



VAMS – Technical Interchange Meeting #5, March 8-9, 2005

# ACES Validation Build 3.1.1 CybelePro™

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**Airspace Operation Modeling Branch**  
**March 09, 2005**

# Overview

- **Validation Day 2/19/2004**
- **ACES Functionality**
- **Input Validation: Using Real World Data To Create Inputs**
  - Flight Data Set from
    - Aircraft Situation Display To Industry (ASDI)
    - Bureau of Transportation Statistics (BTS)
  - Airport Capacities, States, and Unimpeded Taxi Time from
    - Aviation System Performance Metrics (ASPM)
- **Output Validation: Analyzing the Results**
  - Airport Comparisons (ASPM)
  - Flight Statistics Comparisons (BTS)

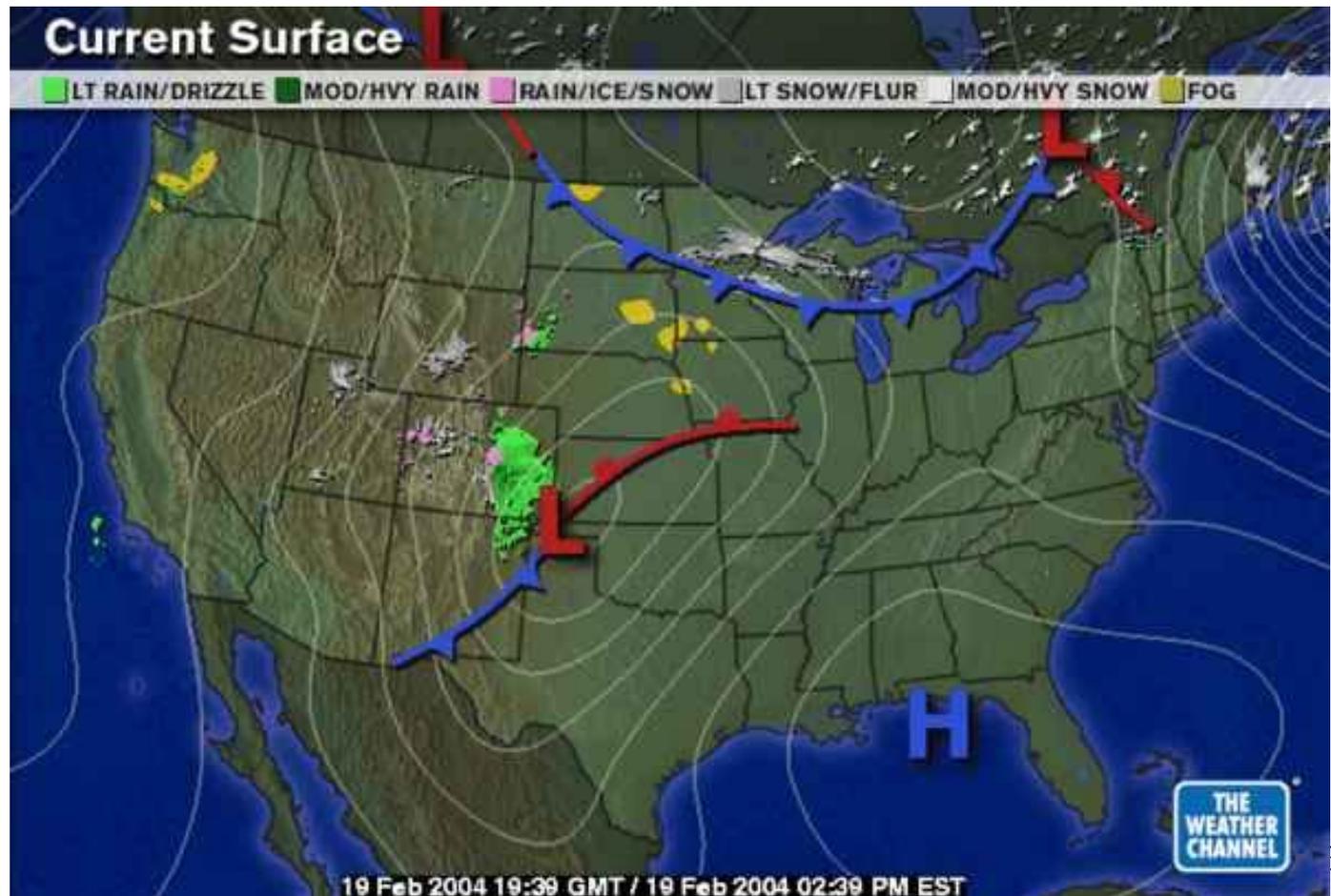
# Sample Day

2/19/2004:

High Traffic

Good Weather

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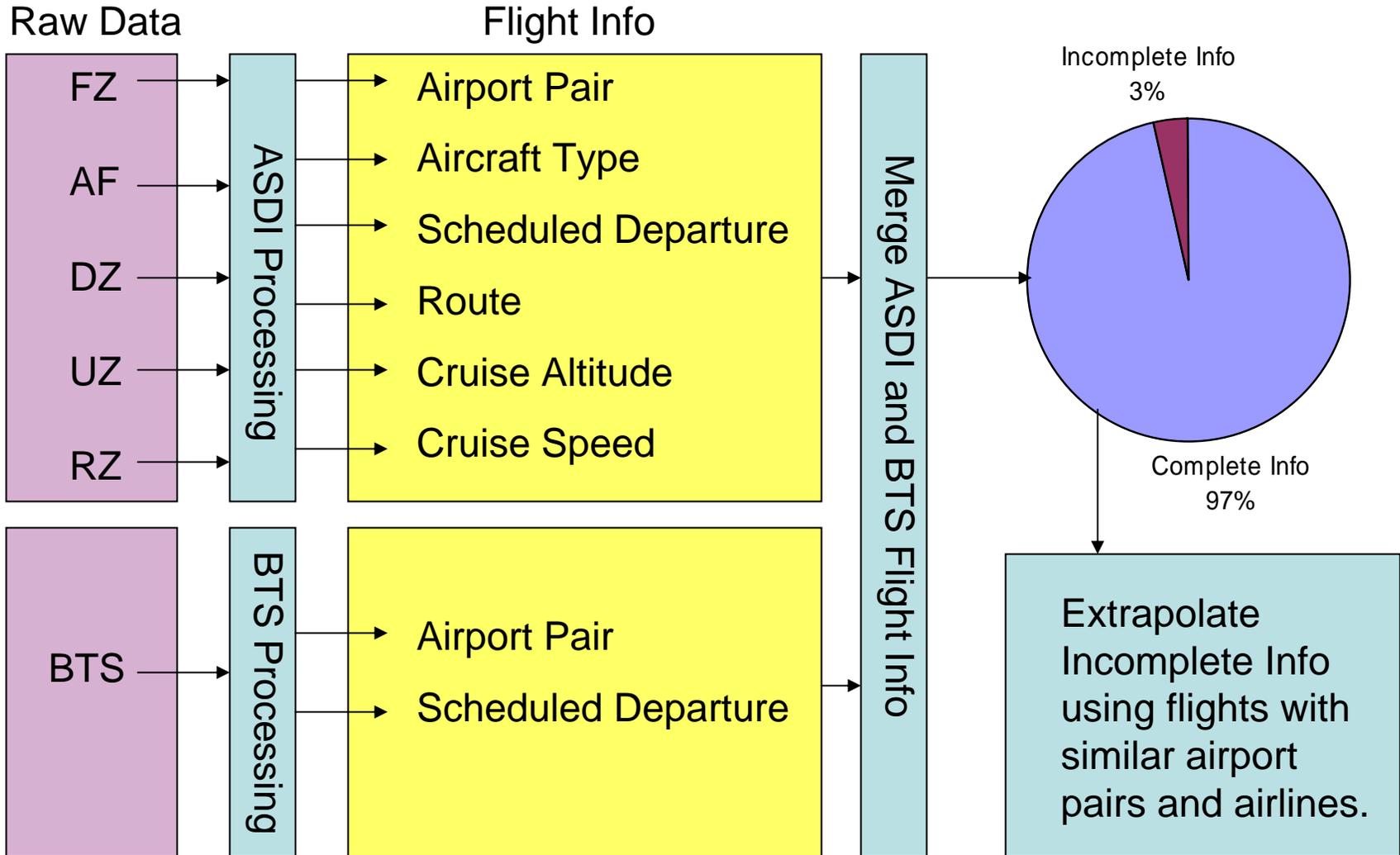


# ACES Functionality

- **Utilized**
  - Delay Maneuvers due to Airport Arrival and Sector Capacity Limits
  - Departure Meter Fix Separation
  - Winds for 2/19/2004
  - International Flights
- **Not Utilized (Keep It Simple!)**
  - Airline Operations Control
  - Enhanced Terminal Area
  - Rerouting
  - Surface Traffic Limitations
  - Conflict Detection & Resolution

# Flight Data Set Construction

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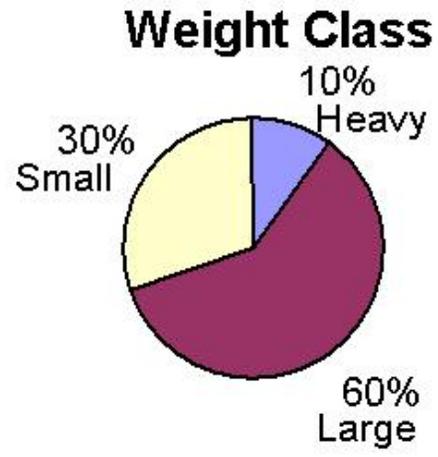
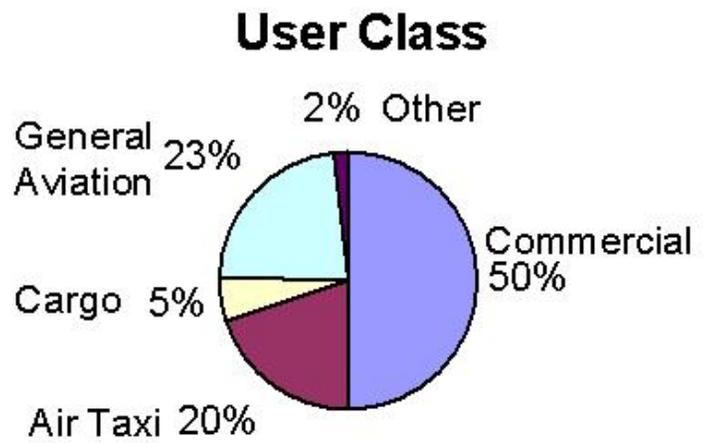
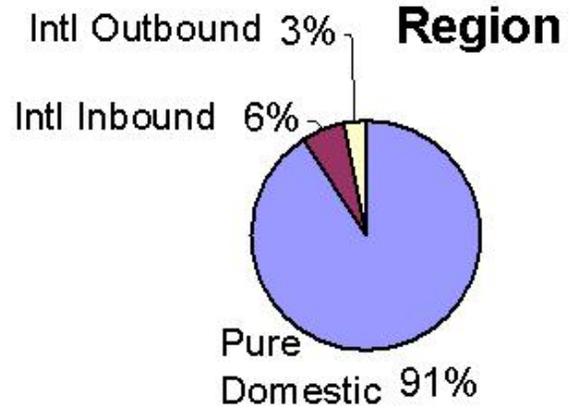


# Flights Flown Statistics

Total Flights = 46243	Counts	Percentage (%)
<b>User Type</b>		
Commercial	<b>23,159</b>	<b>50.1</b>
Air Taxi	<b>9,230</b>	<b>20.0</b>
Cargo	<b>2,445</b>	<b>5.2</b>
GA	<b>10,574</b>	<b>22.9</b>
Other	<b>835</b>	<b>1.8</b>
<b>Weight Class</b>		
Heavy	<b>4,619</b>	<b>10.0</b>
Large	<b>27,418</b>	<b>59.4</b>
Small	<b>14,043</b>	<b>30.6</b>
<b>Physical Class</b>		
Jet	<b>33,023</b>	<b>71.4</b>
Turbo	<b>7,426</b>	<b>16.1</b>
Piston	<b>5,790</b>	<b>12.5</b>
<b>ASPM Flights</b>		
ASPM to Other	<b>10,626</b>	<b>23.0</b>
Other to ASPM	<b>9,715</b>	<b>21.0</b>
ASPM to ASPM	<b>15,194</b>	<b>32.8</b>
Other to Other	<b>10,708</b>	<b>23.2</b>
<b>Flight Count by Region</b>		
Pure Domestic	<b>41,908</b>	<b>90.6</b>
International Inbound	<b>2,765</b>	<b>6.0</b>
International Outbound	<b>1,570</b>	<b>3.4</b>

# Flights Flown Statistics

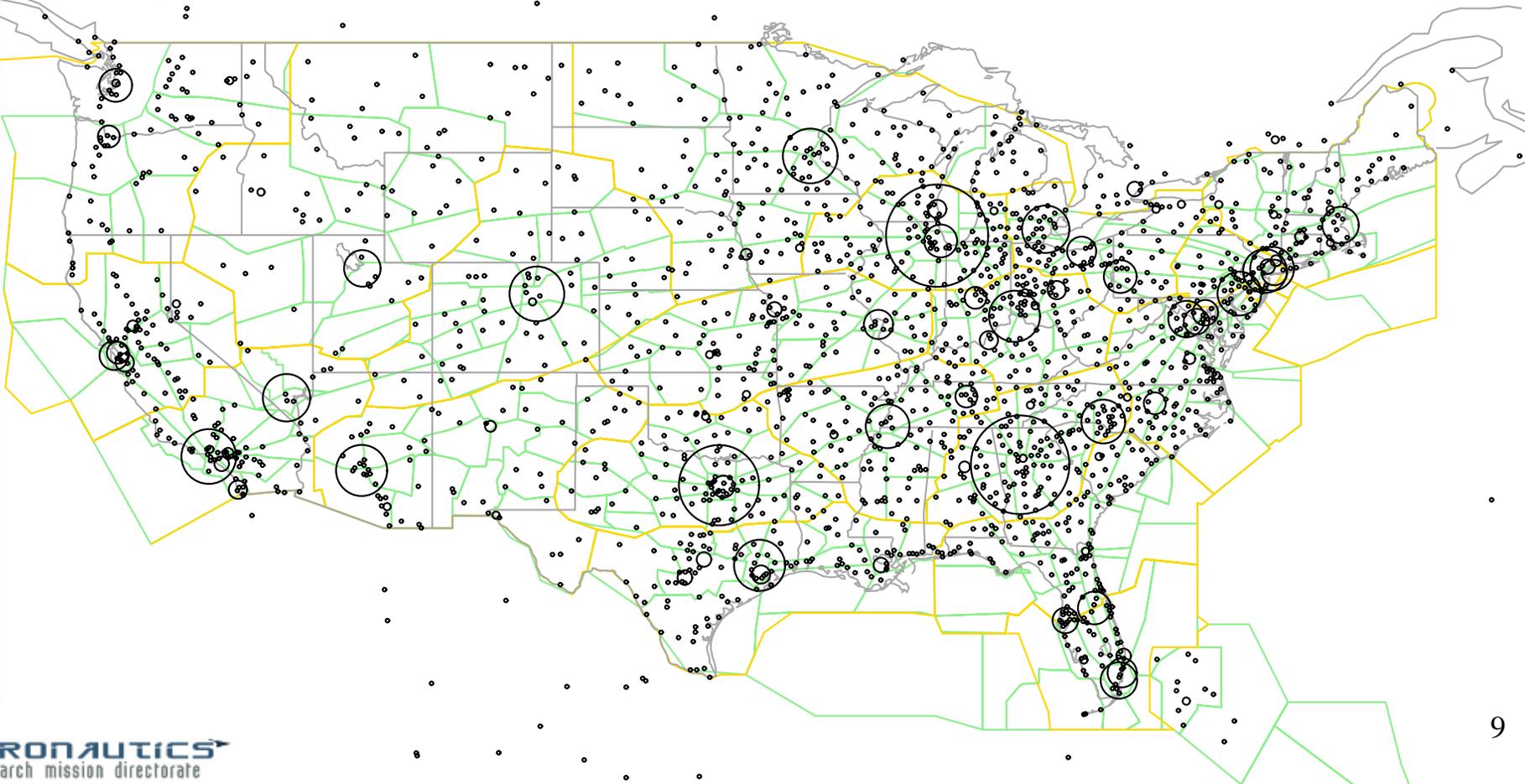
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# Flights Flown Statistics

- **Airports Simulated**
  - US Domestic=1669
  - International=160

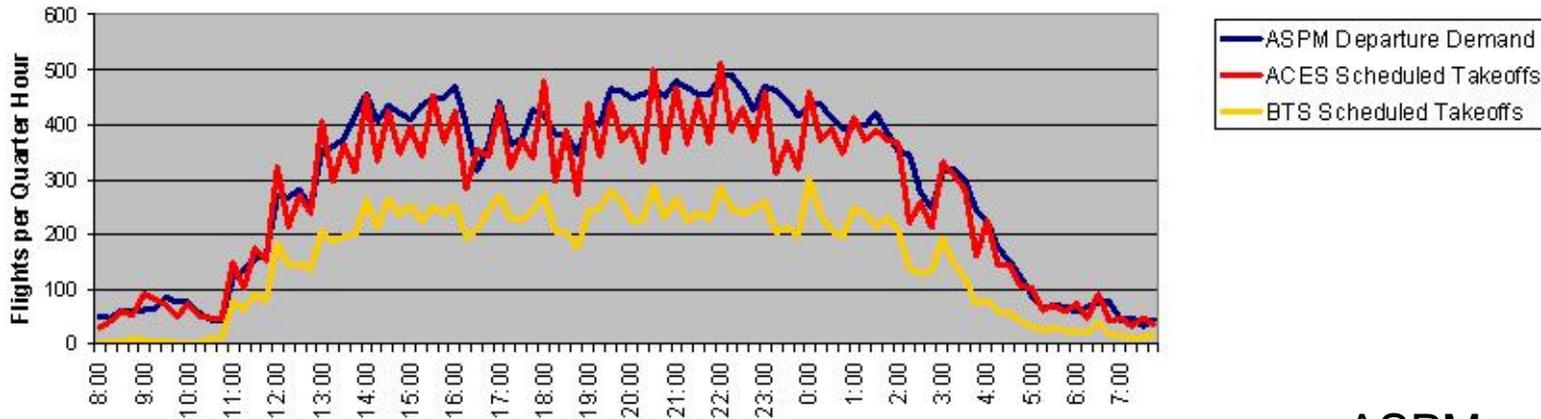
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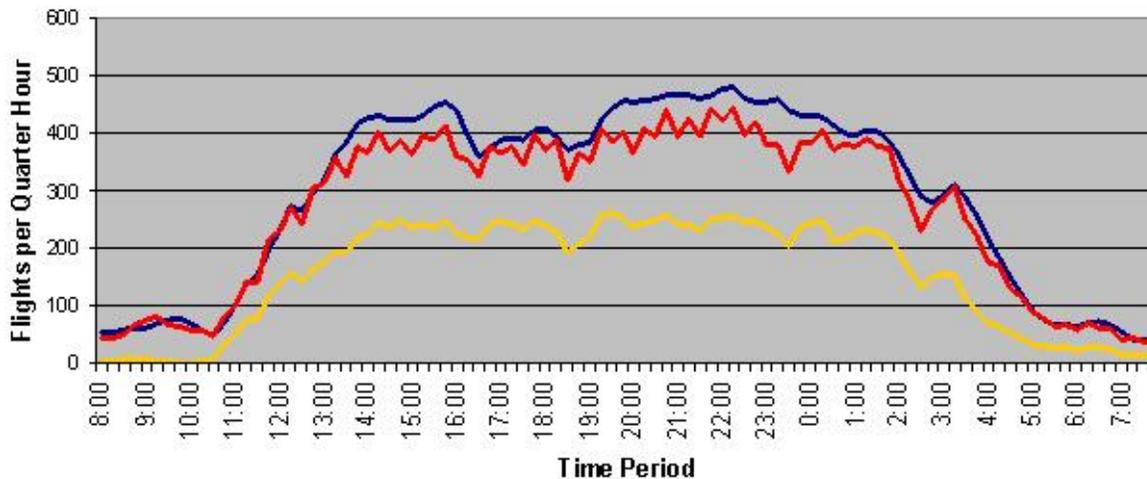
# Total Flight Counts For ASPM Airports

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Total ASPM Airport Departure Dem and



Total ASPM Airport Departure Dem and (Smoothed by Three Qtr Hours)



## ASPM vs. ACES

Correlation	96.2%
Smoothed Correlation	99.1%
Average Difference (ASPM-ACES) per qtr per airport	0.5
Percent ASPM Traffic	91.0%

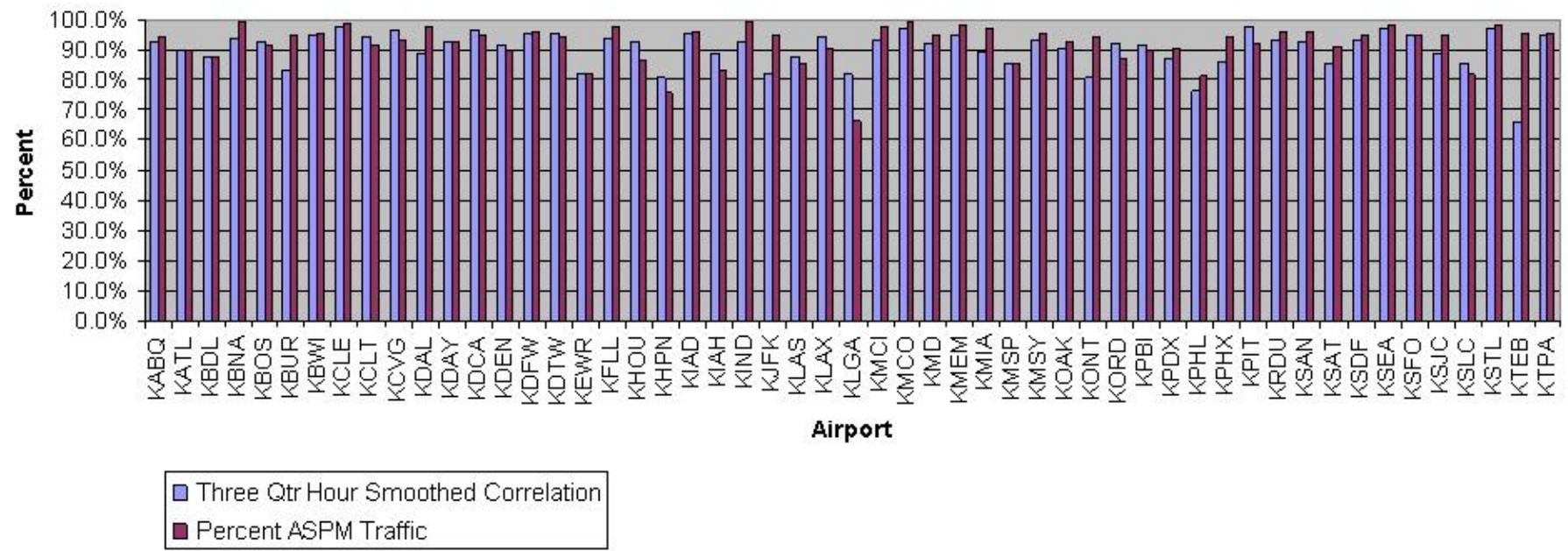
# ASPM Metric Limitations

- **Departure Demand Definition–**  
“... a departure may produce **more than one** quarter hour demand units if the difference between wheels off and actual wheels off spans more than one quarter hour period.”
- **From ASPM Definition For  
Airport Efficiency By Qtr Hour Report**
- **Percent ASPM Traffic is likely greater than 91.0%**

# Airport Departure Demand Comparison

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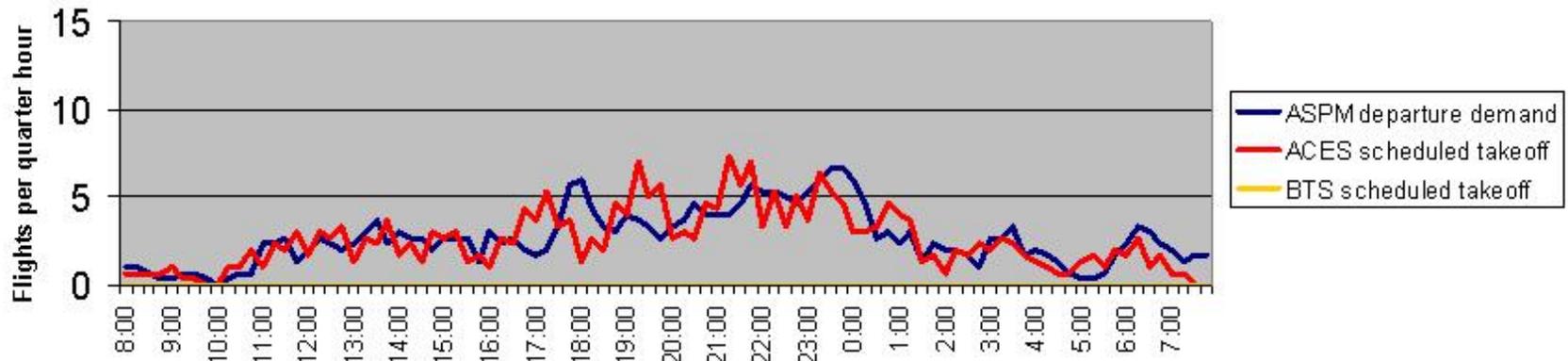
**ACES ASPM Demand Comparison**



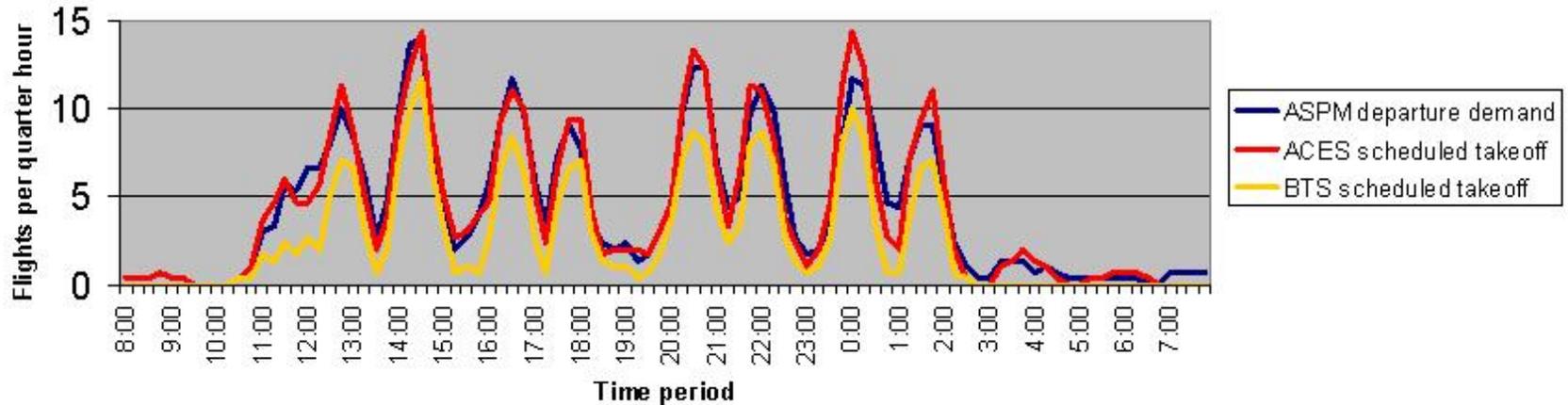
Departure Demand	Average	Min/Apt	Max/Apt
Correlation	90.5%	65.8% KTEB	97.6% KCLE
Percent Traffic	92.3%	66.1% KLGA	99.6% KBNA

# Airports With Highest and Lowest VAMS Correlation

## Lowest KTEB Departure Demand (Smoothed by 3 qtr hours)

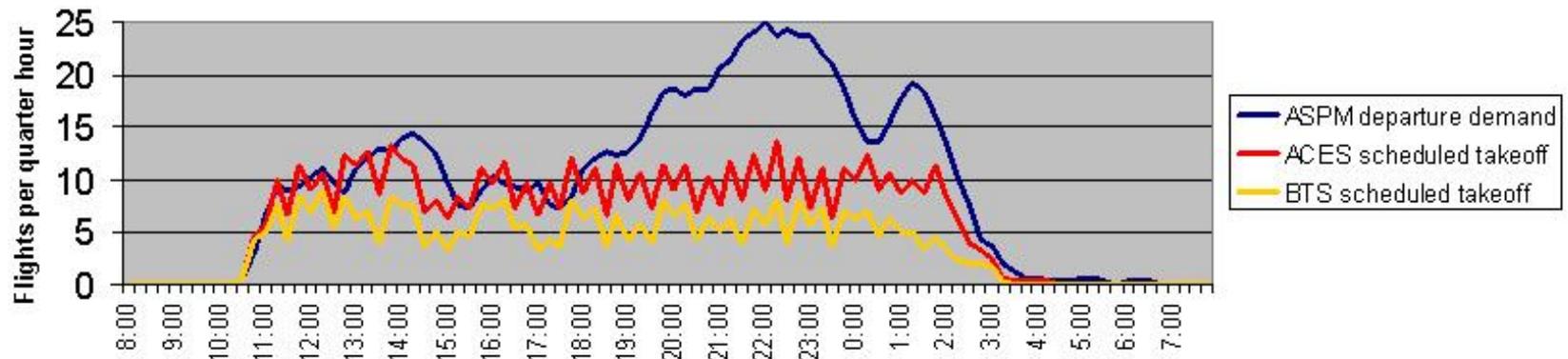


## Highest KCLE Departure Demand (Smoothed by 3 qtr hours)

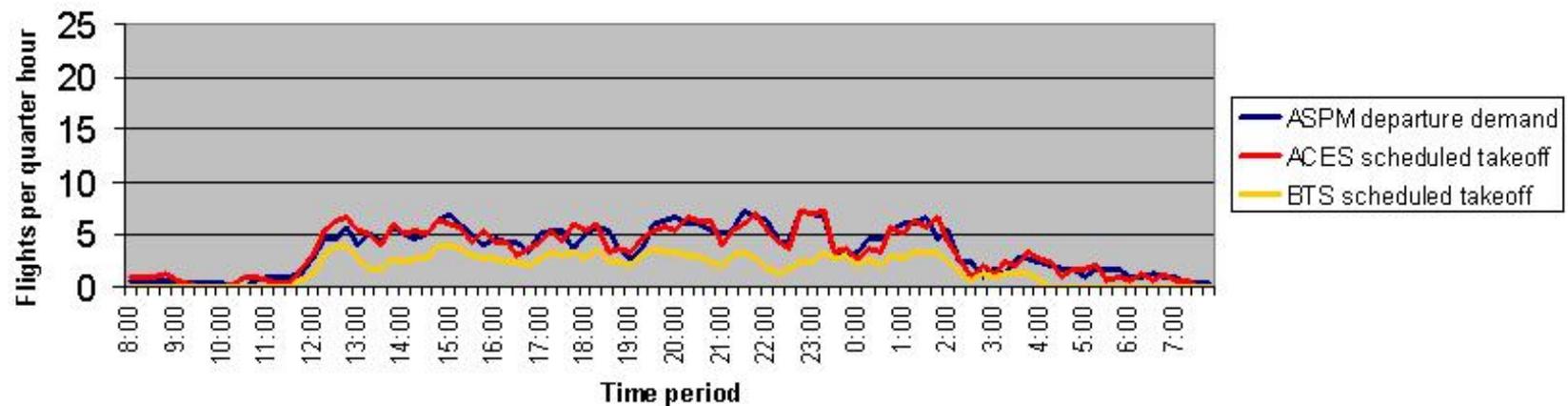


# Airports With Highest and Lowest Percent ASPM Traffic

## Lowest KLG A Departure Demand (Smoothed by 3 qtr hours)



## Highest KBNA Departure Demand (Smoothed by 3 qtr hours)



# Flight Data Set Validation Conclusions

- ACES Scheduled Takeoff correlate quite well to ASPM departure demand.
- Percent ASPM Traffic is likely greater than 91.0% due to multiple counts for some delayed flights in ASPM departure demand.
- ~4% original ASPM flights were filtered due to distance < 80nmi.

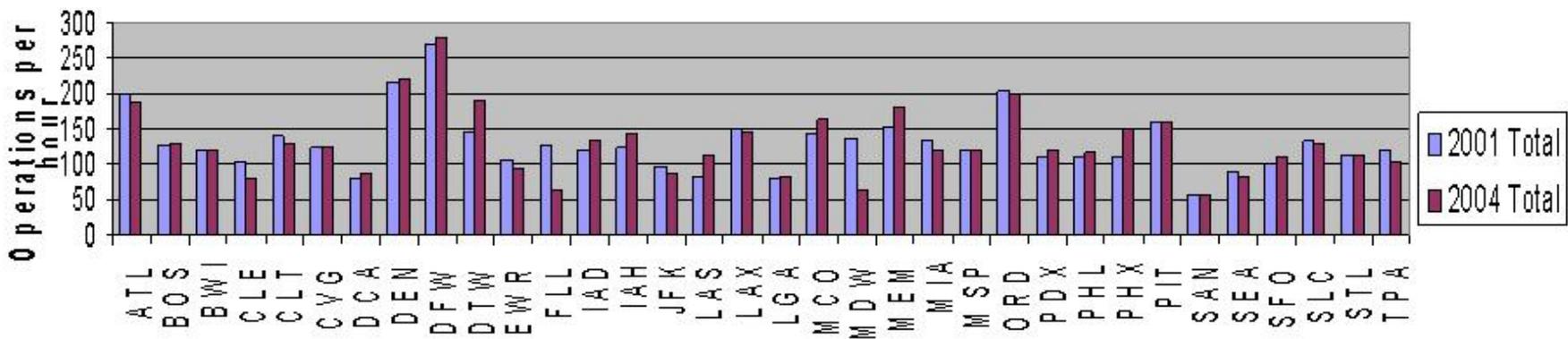
# Creating Airport Capacities and States from ASPM

- **Method To Date**
  - VFR/IFR states from ASPM
  - Capacities from sample Top250AirportCapacity.csv file
    - Top 30 airports from 2001 Benchmark report
    - Remaining airports given generic capacities based on number of runways.
- **Other Available Resources**
  - 2004 Benchmark report
  - ASPM Published Airport Rates
  - ASPM Actual Throughput

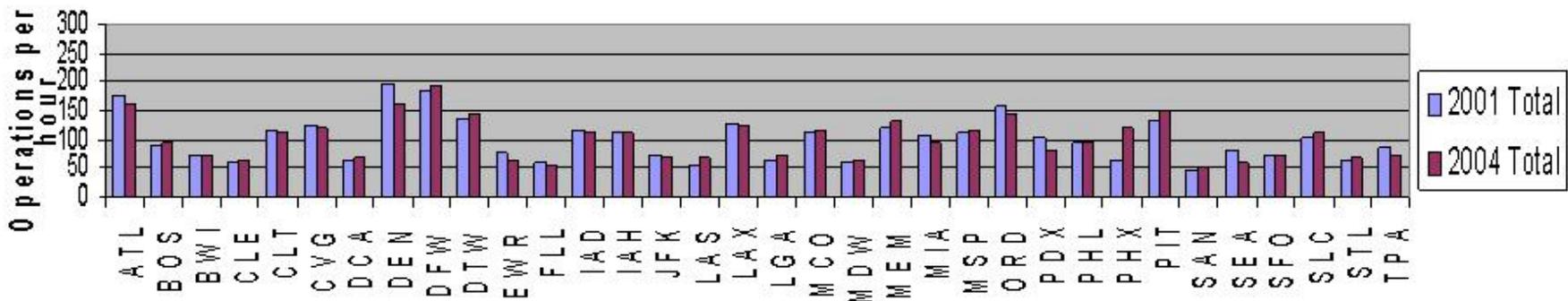
# Benchmark Report: 2001 vs. 2004

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## VFR Capacity Changes



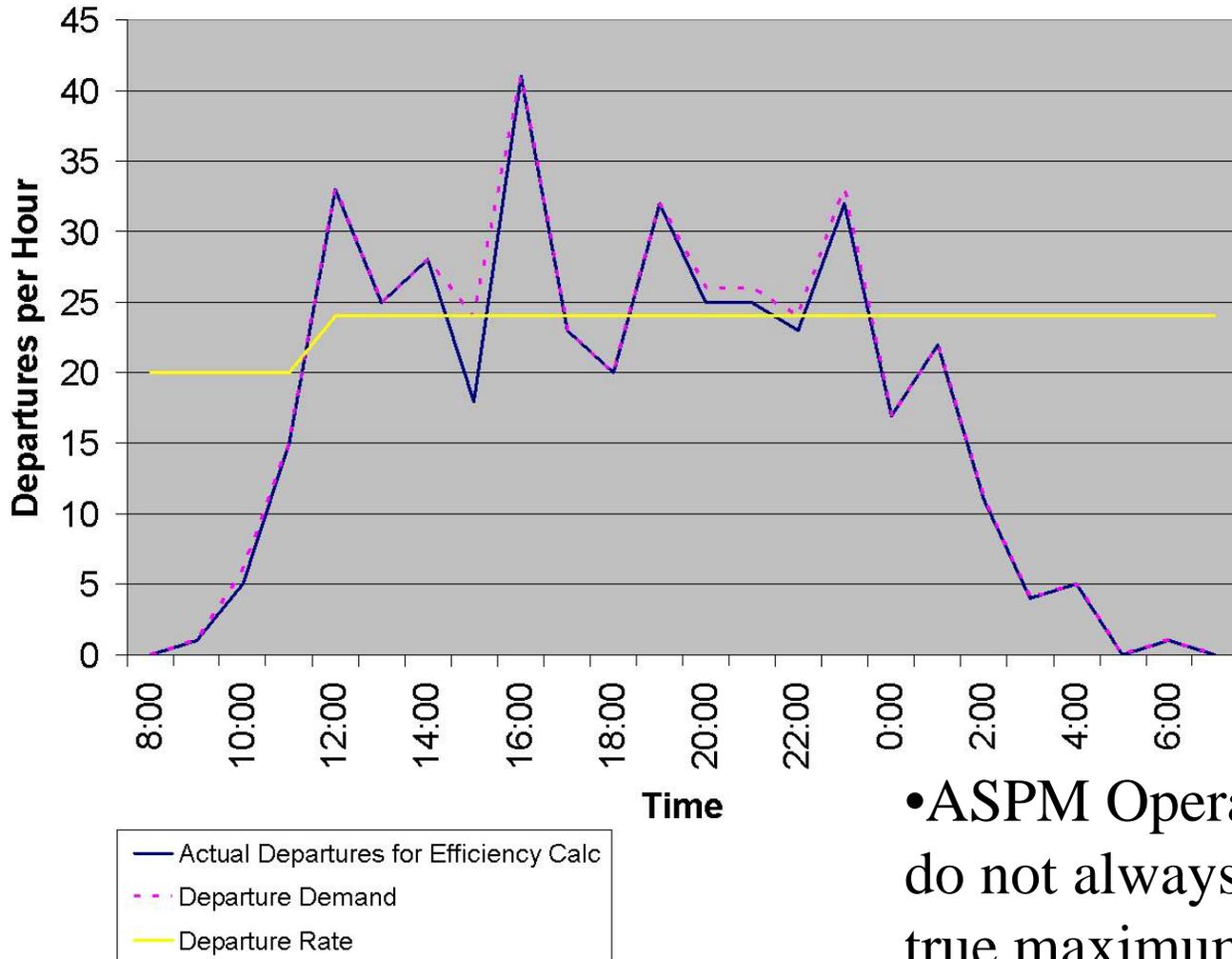
## IFR Capacity Changes



Airport

# ASPM Published Airport Data

## KFLL ASPM Published Departure Stats



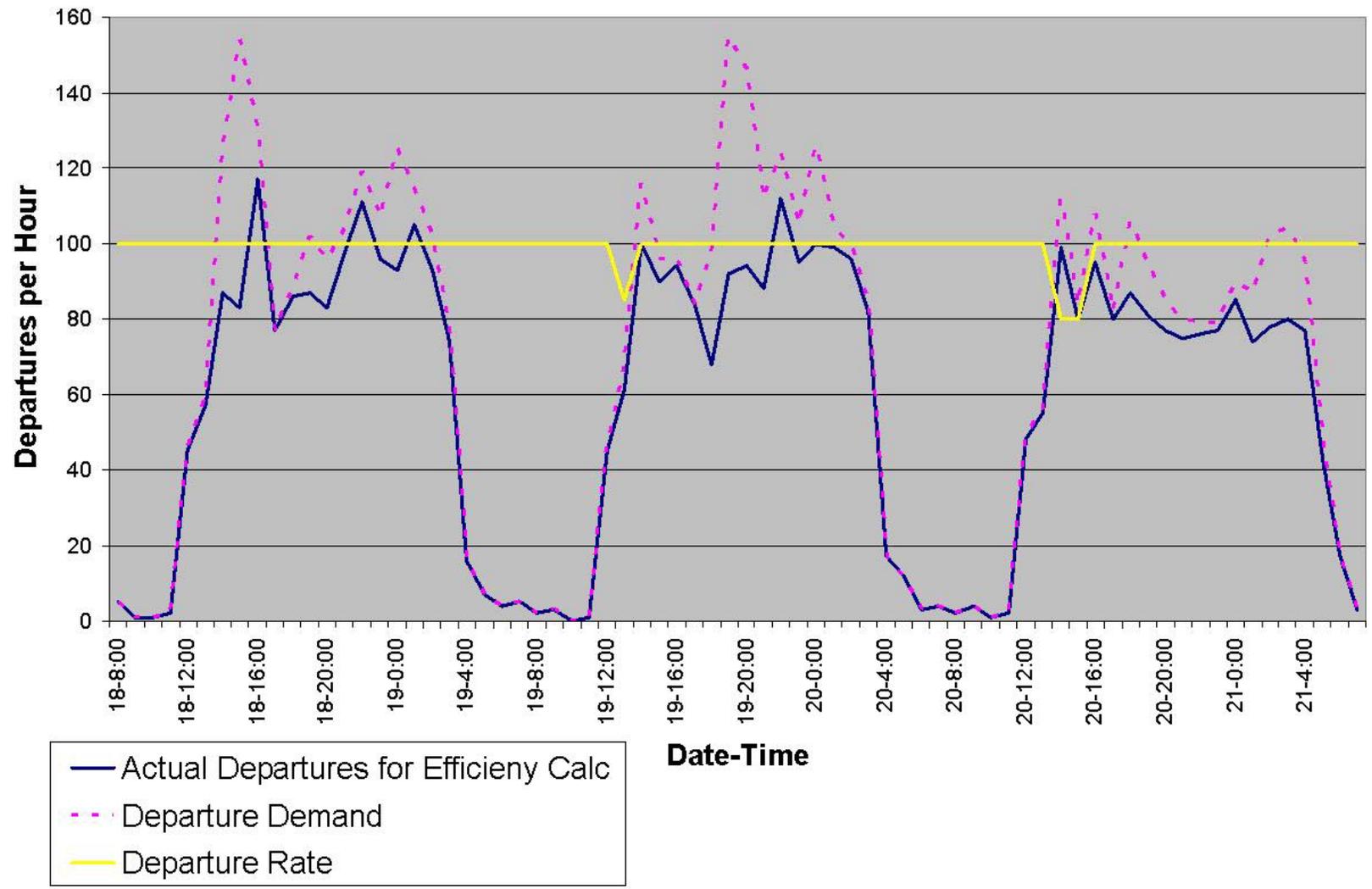
• ASPM Operation Rates do not always reflect true maximums

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# ASPM Published Airport Data

## KORD ASPM Published Departure Stats

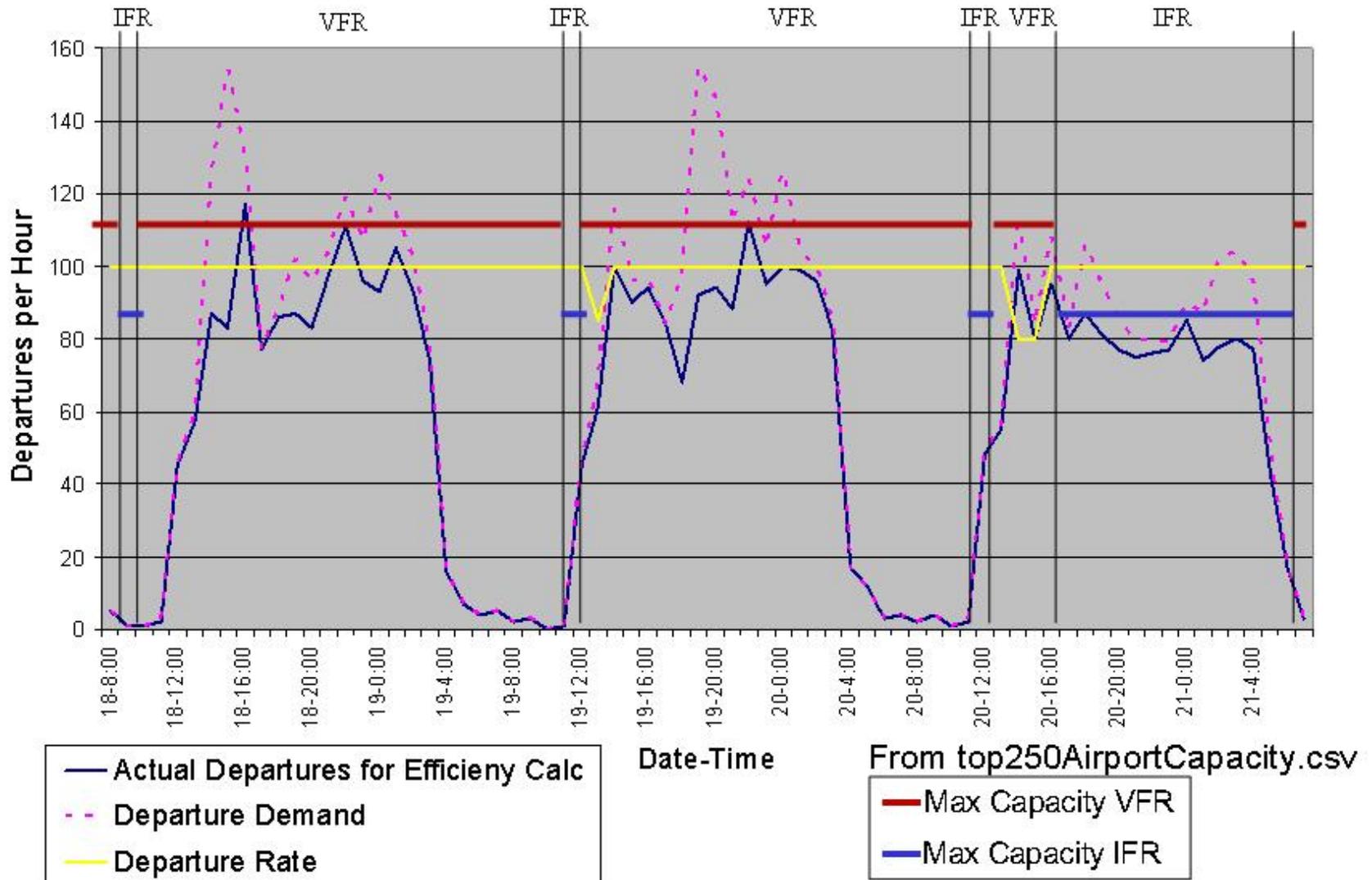
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# ASPM Published Airport Data

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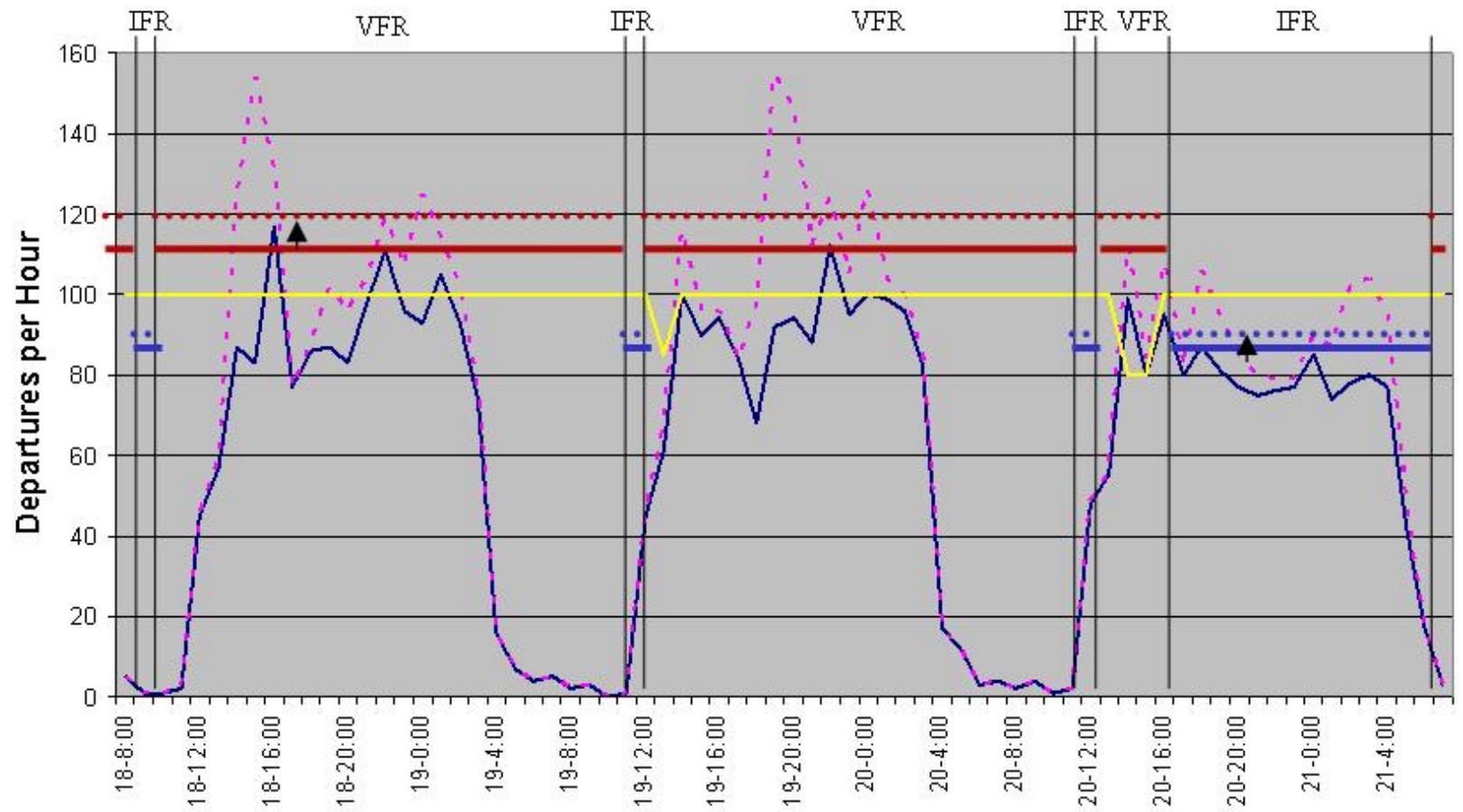
## KORD ASPM Published Departure Stats



# ASPM Published Airport Data

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## KORD ASPM Published Departure Stats



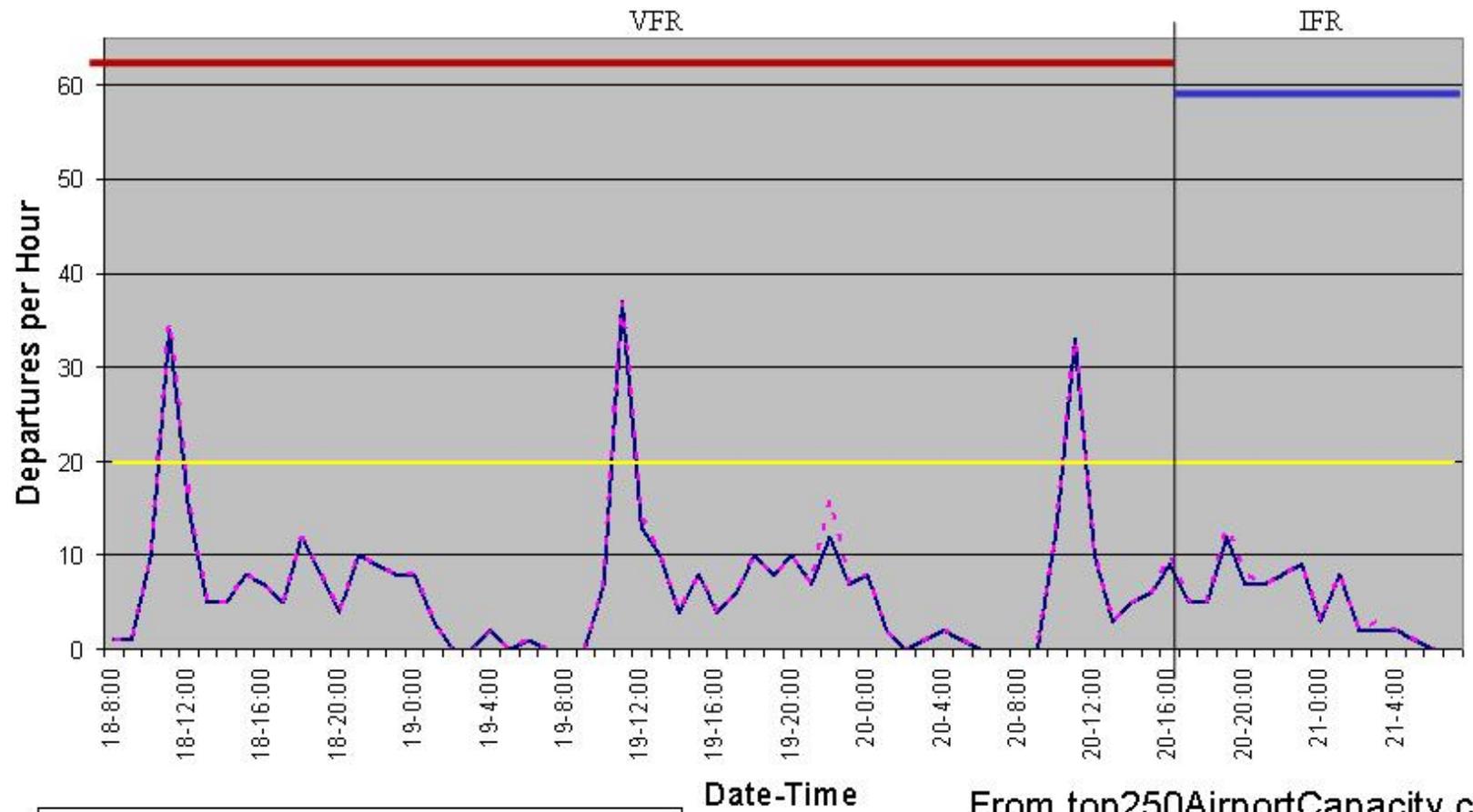
— Actual Departures for Efficient Calc  
 - - - Departure Demand  
 — Departure Rate

From top250AirportCapacity.csv  
 — Max Capacity VFR  
 — Max Capacity IFR

# ASPM Published Airport Data

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## KDAY ASPM Published Departure Stats



— Actual Departures for Efficiency Calc  
- - - Departure Demand  
— Departure Rate

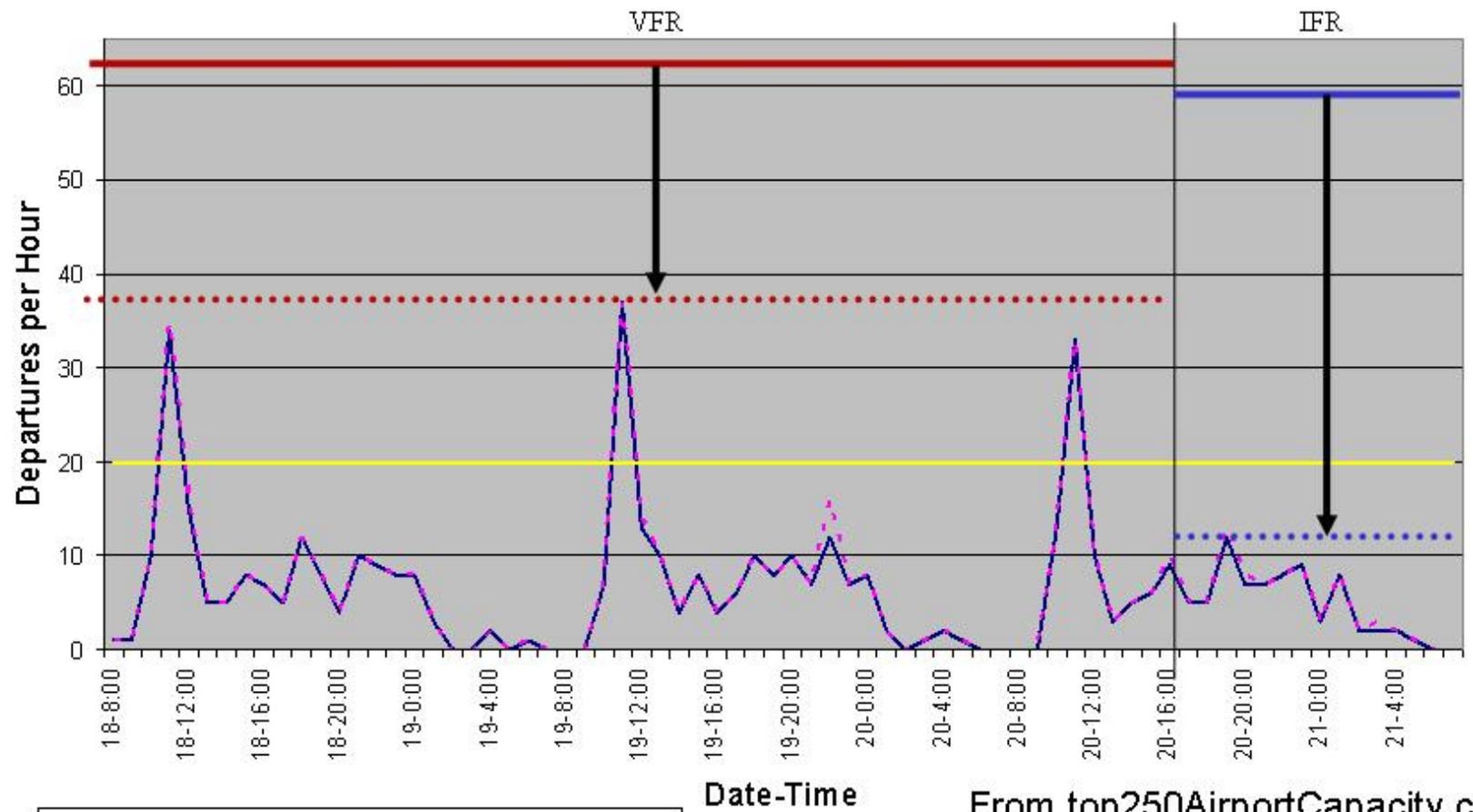
— Max Capacity VFR  
— Max Capacity IFR

From top250AirportCapacity.csv

# ASPM Published Airport Data

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## KDAY ASPM Published Departure Stats



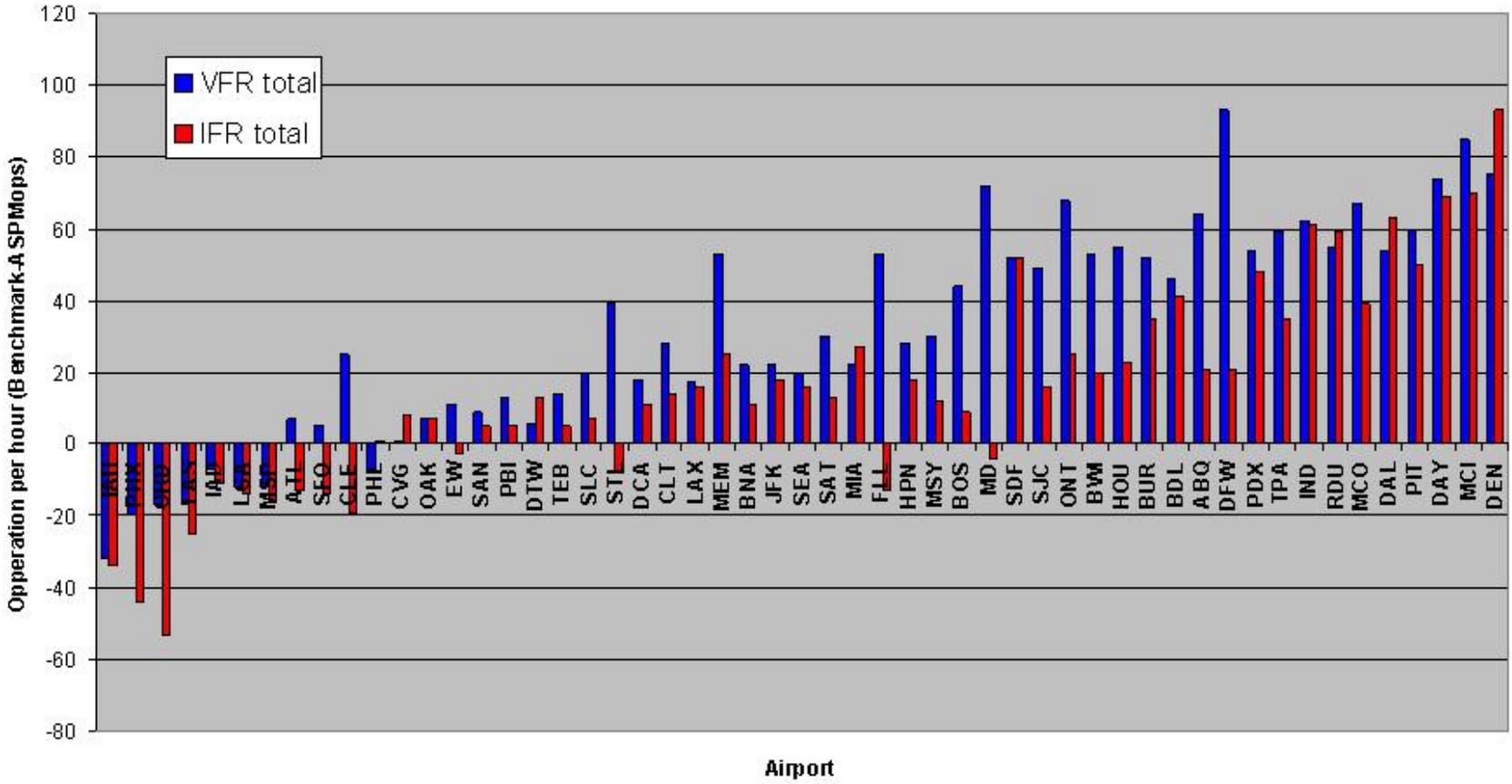
— Actual Departures for Efficiency Calc  
 - - - Departure Demand  
 — Departure Rate

From top250AirportCapacity.csv  
 — Max Capacity VFR  
 — Max Capacity IFR

# ACES Sample (top250AirportCapacity.csv) vs. Max Airport Throughput

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Total Capacity Difference (ACES sample - maximum throughput)



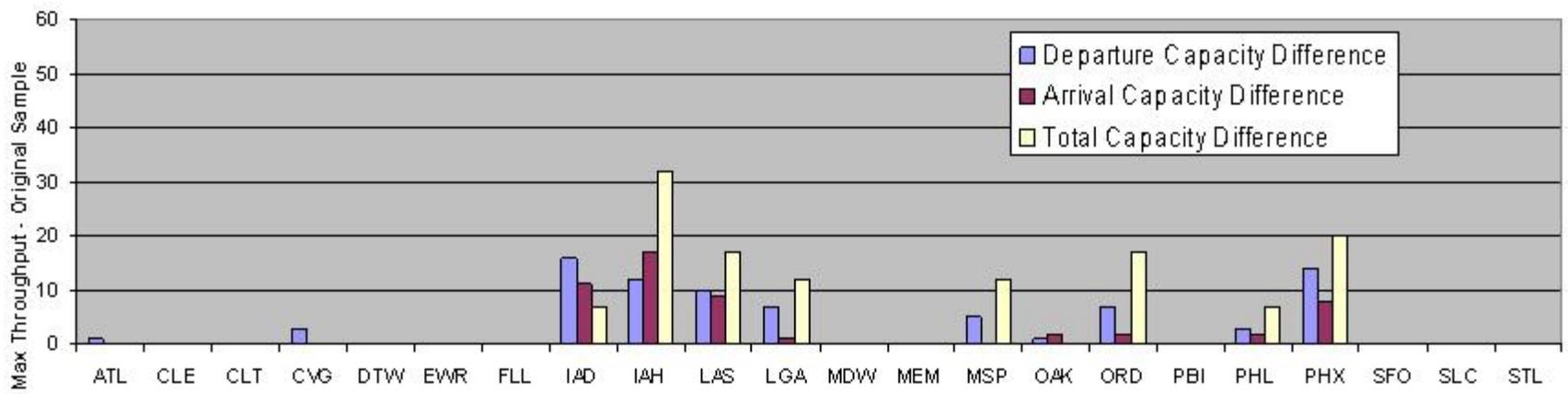
## Throughput as Maximum Capacities

- Under utilized airports may have underestimated capacity.
- Congested airports may have overestimated capacity.
- All capacities fed into ACES are  $\geq$  actual real world throughput, even if they may be  $<$  demand.
- Unlike the real world ACES treats maximum capacity as a hard maximum.
- Force conservative ACES models to allow real world throughput.
- Possibility of using the maximum capacity between the original ACES sample and max throughput method.

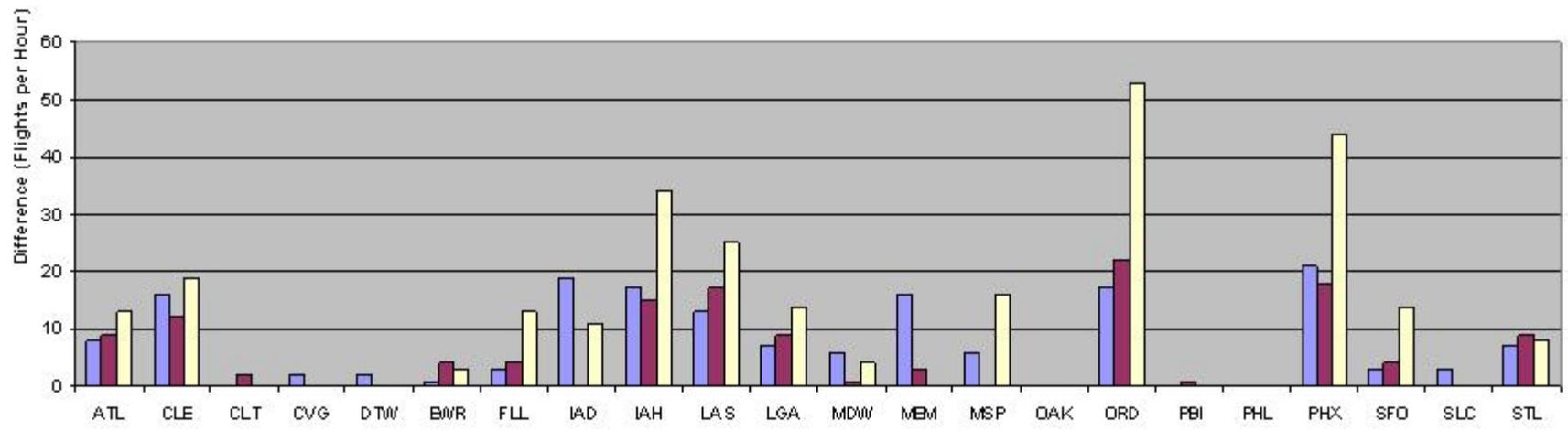
# Using Only Max of Throughput Greater Than The Original ACES Sample

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## VFR



## IFR



# METAR Data

- **Terminal Area Weather Conditions including Ceiling and Visibility**
- **Over 1800 US airports**
- **Reported hourly**
- **Ceiling and Visibility used to estimate State**
  
- **Most non ASPM airports**
  - Single runway generic capacity assignments
  - Do not reach maximum capacity in current day
  - VFR ceiling and visibility requirements unknown
  
- **Conclusion**
  - Better suited for future demand cases
  - Leave all non ASPM airport in VFR state

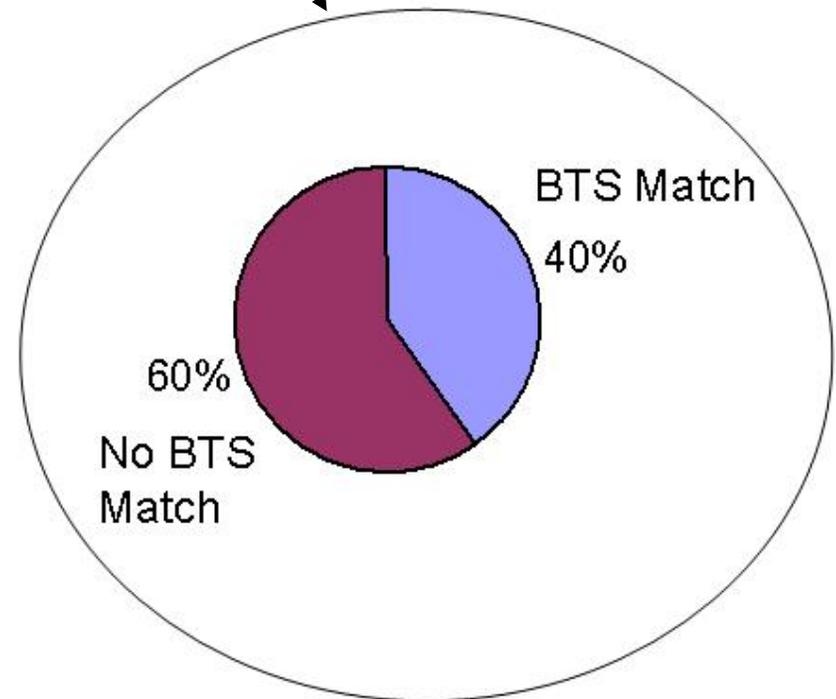
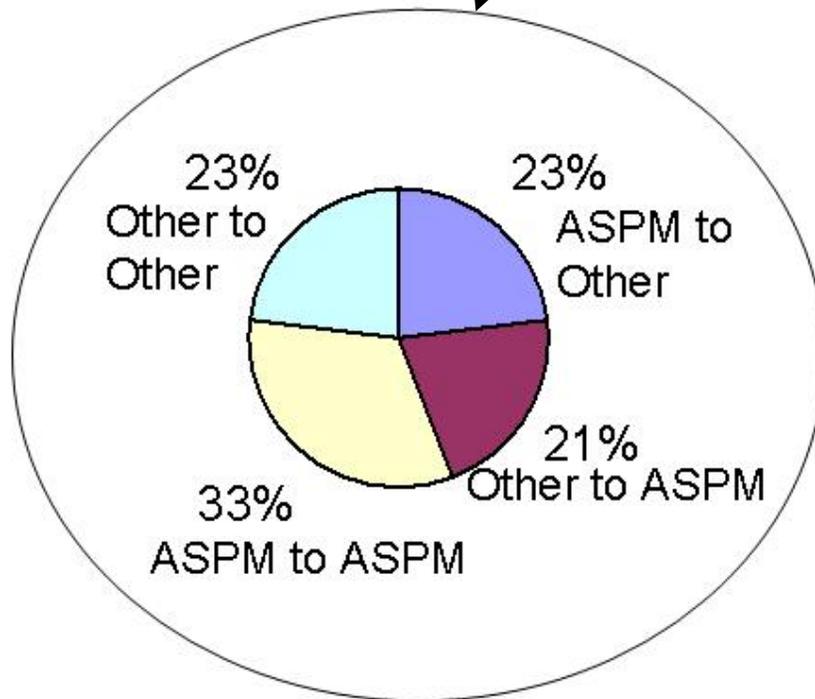
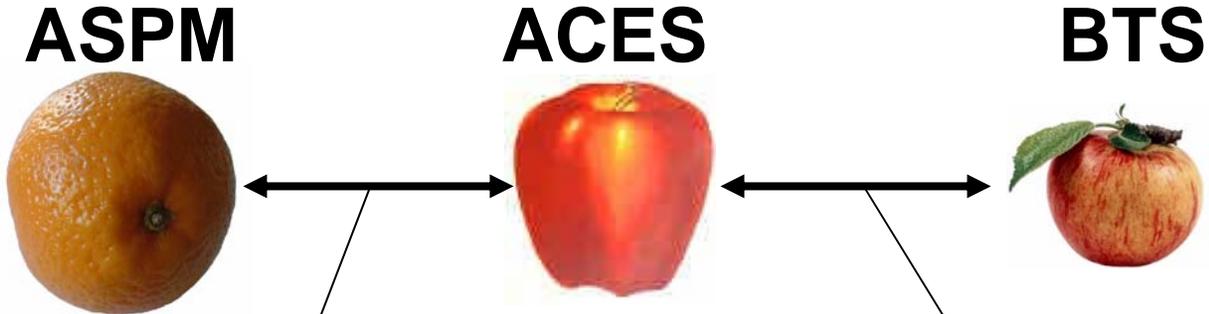
	Dep	Arr	Tot
VFR	31	31	55
IFR	30	30	53

# Input Validation Summary

- **Validation Day 2/19/2004**
- **Flight Data Set**
  - FDS info from ASDI NAS messages matched to BTS flights
  - 41908 domestic and 4335 international flights flown
  - Average of 91% or more airport traffic simulated for ASPM airports
  - Average of 0.5 flights per quarter hour per airport lower than ASPM
- **Airport Capacity and State**
  - Maximum throughput and ASPM states for ASPM airports
  - Default capacity and VFR state for remaining airports
- **Future Cases**
  - Maximum throughput only when higher than the default capacity.

# Real World Data Sources for Results Analysis

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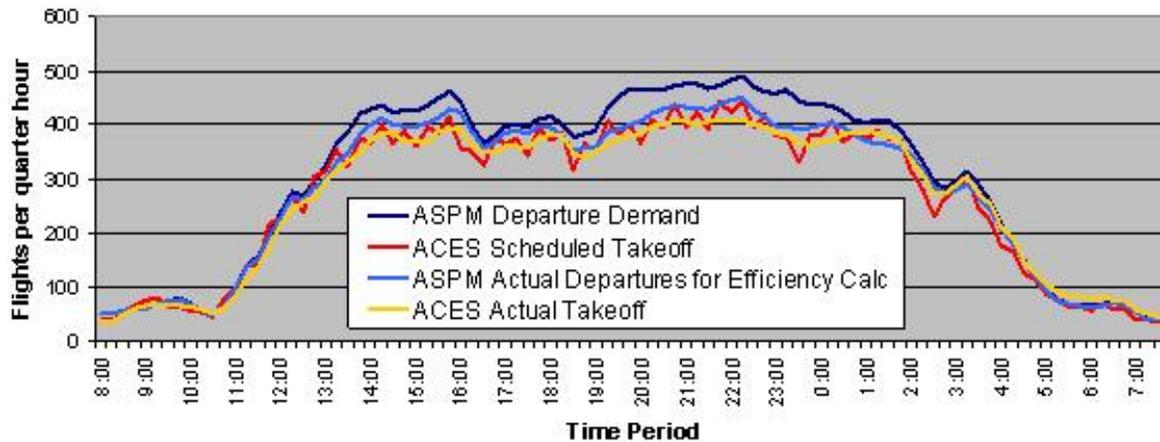


# The ASPM Data Orange

- **Only summary statistics are available at current security clearance.**
  - ASPM flight base cannot be matched to ACES for a properly filtered delay statistics comparison.
  - Only flight counts may be used to ensure realistic level of traffic.
- **Both Departure and Arrival demand may have multiple counts for flights delayed across one or more quarter hour divisions.**
  - Departure Demand is 7% higher than Actual Departures
  - Arrival Demand is 9% higher than Actual Arrivals
- **Best Source for Full Traffic Comparisons At Airports**

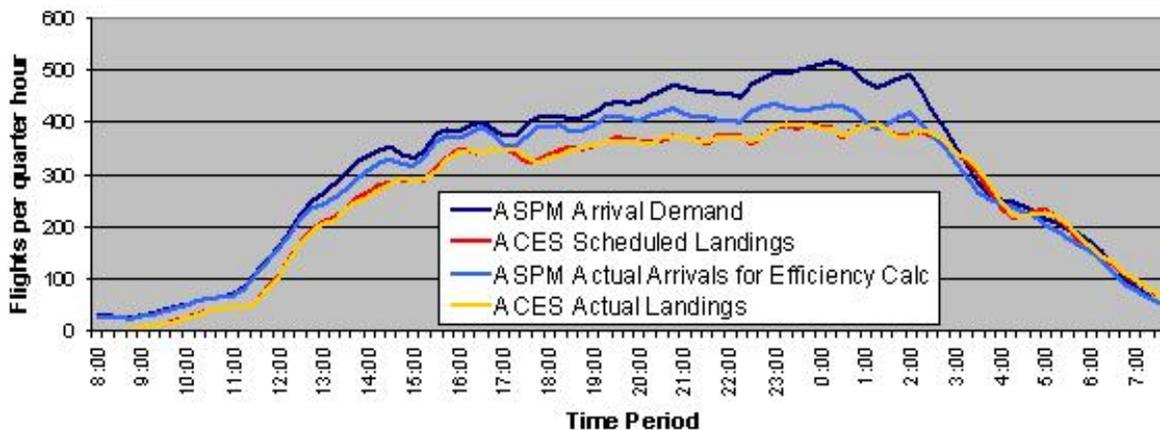
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**ASPM Airport Departures (Smoothed by 3 qtr hours)**



Arrivals	Sched	Actual
Correlation	97.5%	97.4%
Smoothed Correlation	98.3%	98.3%
Average Difference (ASPM-ACES) per qtr per airport	0.88	0.38
Percent ASPM Traffic	84.4%	92.6%

**ASPM Airport Arrivals (Smoothed by 3 qtr hours)**

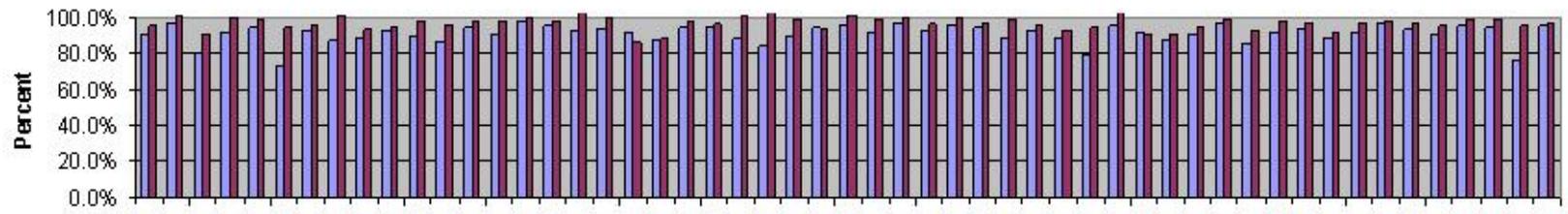


Departures	Sched	Actual
Correlation	96.2%	98.7%
Smoothed Correlation	99.1%	99.6%
Average Difference (ASPM-ACES) per qtr per airport	0.5	0.1
Percent ASPM Traffic	91.0%	97.9%

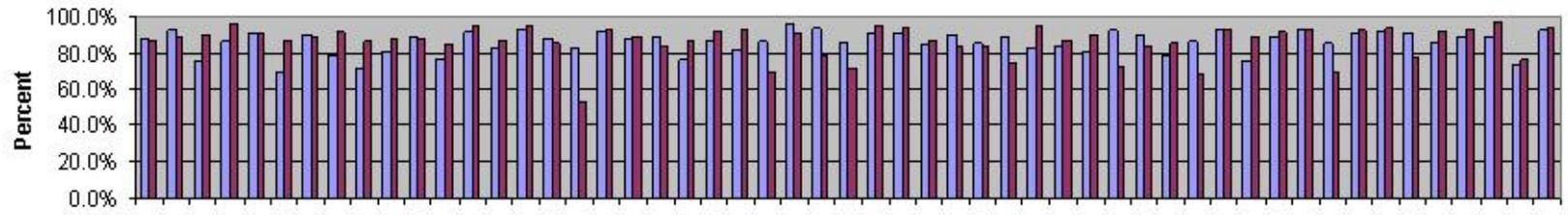
# Results: ACES vs. ASPM by Airport

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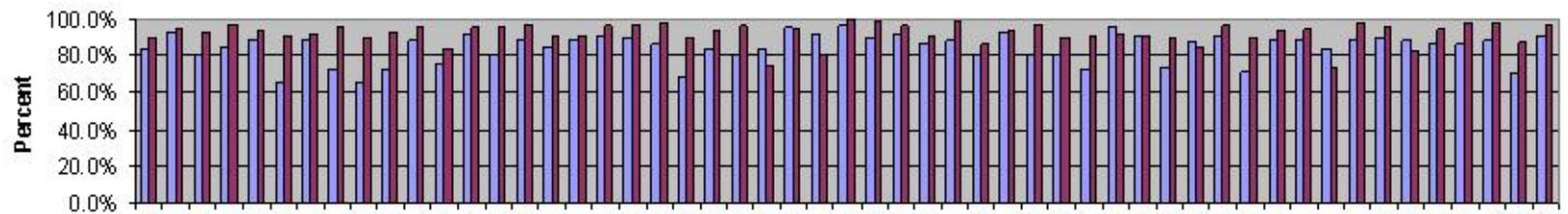
Actual Departure Airport Comparison



Arrival Demand Airport Comparison



Actual Arrival Airport Comparison



Airport	Three Gtr Hour Smoothed Correlation (%)	Percent ASPM Traffic (%)
KABQ	95	90
KATL	95	95
KBDL	85	90
KBNA	95	95
KBOS	95	90
KBUR	90	95
KBWI	95	90
KCLE	90	95
KCLT	90	90
KCVG	90	95
KDAL	95	90
KDAY	90	95
KDCA	95	90
KDEN	95	90
KDFW	95	90
KDTW	90	95
KEWR	90	95
KFLL	95	90
KHOU	95	90
KHPN	90	95
KIAD	90	95
KIAH	95	90
KIND	90	95
KJFK	90	95
KLAS	95	90
KLAX	95	90
KLGA	90	95
KMCI	95	90
KMCO	95	90
KMD	90	95
KMEM	90	95
KMIA	90	95
KMSP	95	90
KMSY	95	90
KOAK	90	95
KONT	90	95
KORD	95	90
KPBI	90	95
KPDX	90	95
KPHL	90	95
KPHX	95	90
KPIT	90	95
KRDU	95	90
KSAN	95	90
KSAT	90	95
KSDF	95	90
KSEA	95	90
KSFO	90	95
KSJC	95	90
KSLC	95	90
KSTL	95	90
KTEB	90	95
KTPA	95	90

# Results: ACES vs. ASPM by Airport

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Departure Demand	Average	Min/Apt	Max/Apt
Correlation	90.5%	65.8% KTEB	97.6% KCLE
Percent Traffic	92.3%	66.1% KLGA	99.6% KBNA

Actual Departure	Average	Min/Apt	Max/Apt
Correlation	91.1%	73.8% KBUR	97.6% KDFW
Percent Traffic	97.1%	86.1% KLGA	114.0% KJFK

Arrival Demand	Average	Min/Apt	Max/Apt
Correlation	86.1%	68.9% KBUR	96.6% KLAS
Percent Traffic	86.4%	53.4% KERW	97.2% KSTL

Actual Arrival	Average	Min/Apt	Max/Apt
Correlation	84.7%	65.4% KBUR	96.6% KLGA
Percent Traffic	92.5%	74.2% KSAT	100.0% KLGA

# Results: ACES vs. ASPM by Airport

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Departure Demand	Average	Min/Apt	Max/Apt
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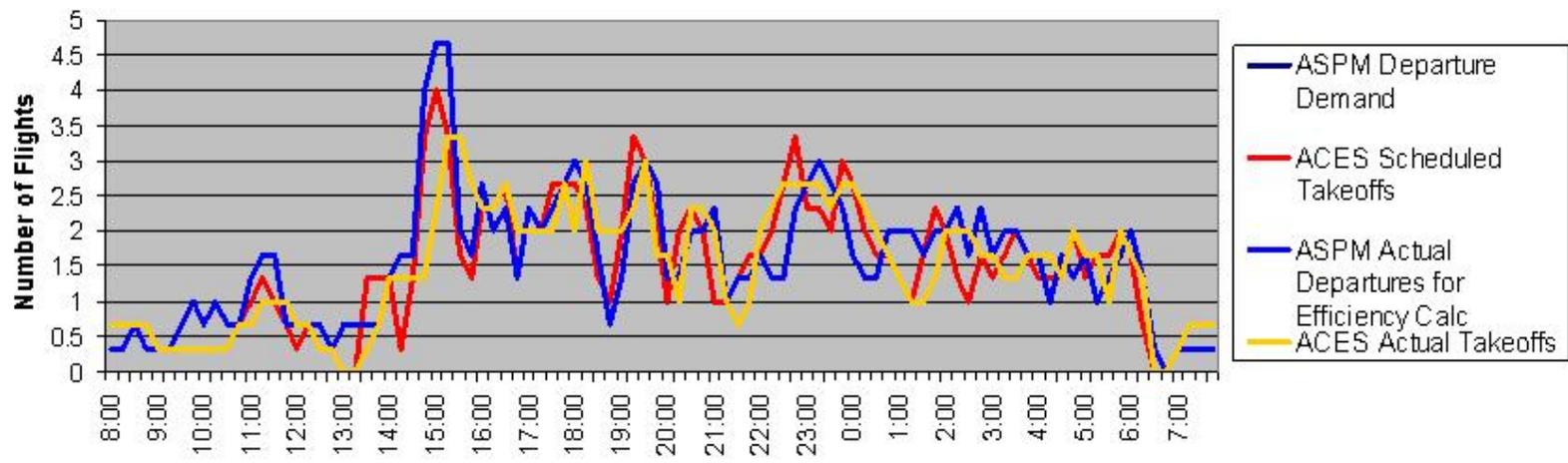
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Percent Traffic	86.4%	53.4% KERW	97.2% KSTL

Actual Arrival	Average	Min/Apt	Max/Apt
Correlation	84.7%	65.4% KBUR	96.6% KLGA
Percent Traffic	92.5%	74.2% KSAT	100.0% KLGA

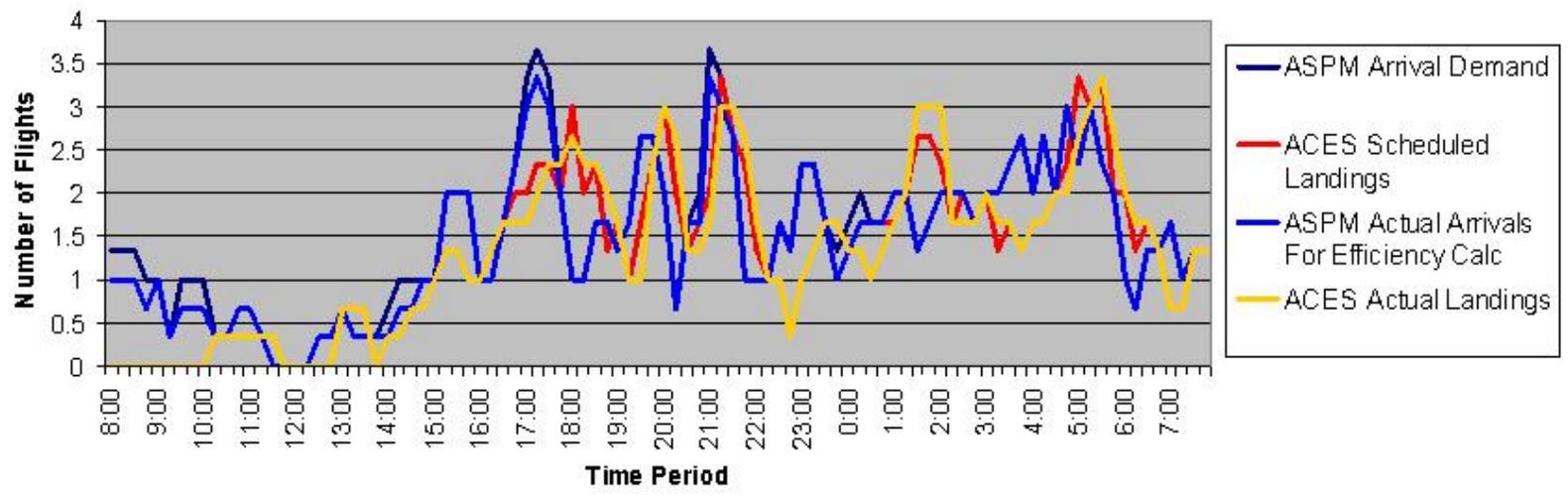
# KBUR Results: Low Correlation

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KBUR Departure Comparison



KBUR Arrival Comparison



# Results: ACES vs. ASPM by Airport

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Departure Demand	Average	Min/Apt	Max/Apt
Correlation	90.5%	65.8% KTEB	97.6% KCLE
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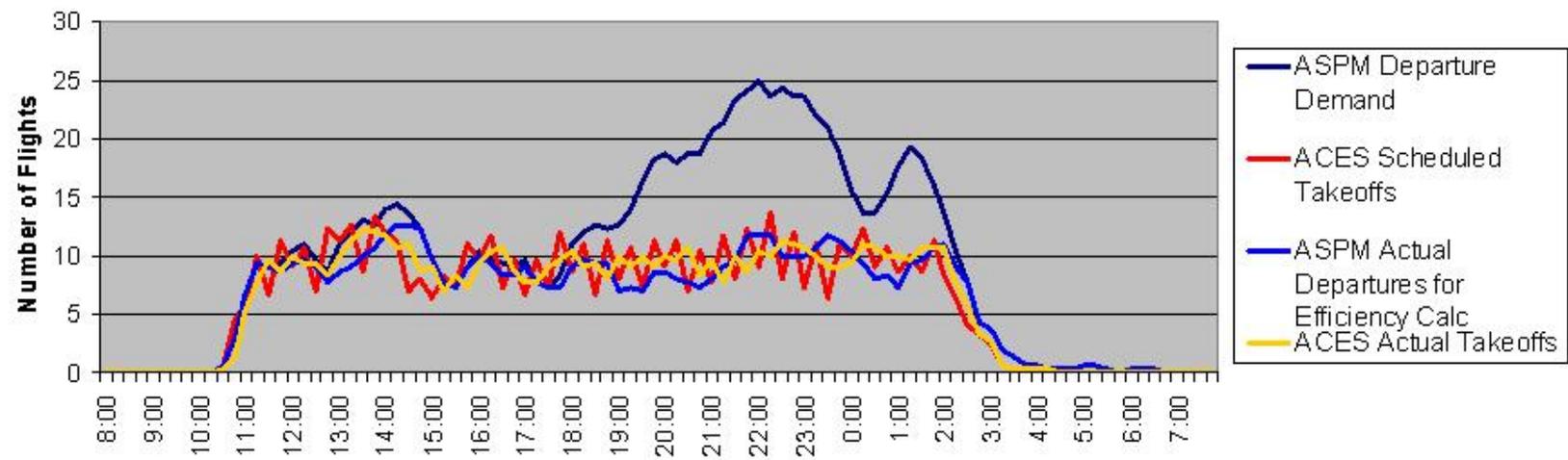
Arrival Demand	Average	Min/Apt	Max/Apt
Correlation	86.1%	68.9% KBUR	96.6% KLAS
Percent Traffic	86.4%	53.4% KERW	97.2% KSTL

Actual Arrival	Average	Min/Apt	Max/Apt
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Percent Traffic	92.5%	74.2% KSAT	100.0% KLGA

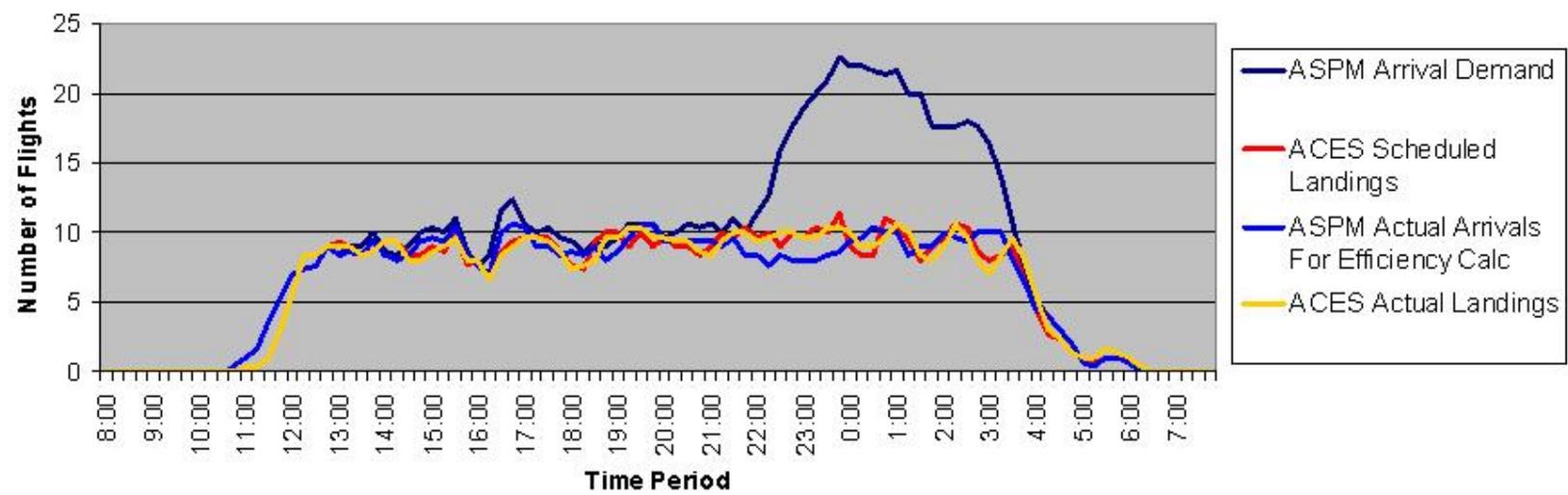
# KLGA Results: Demand vs. Actual

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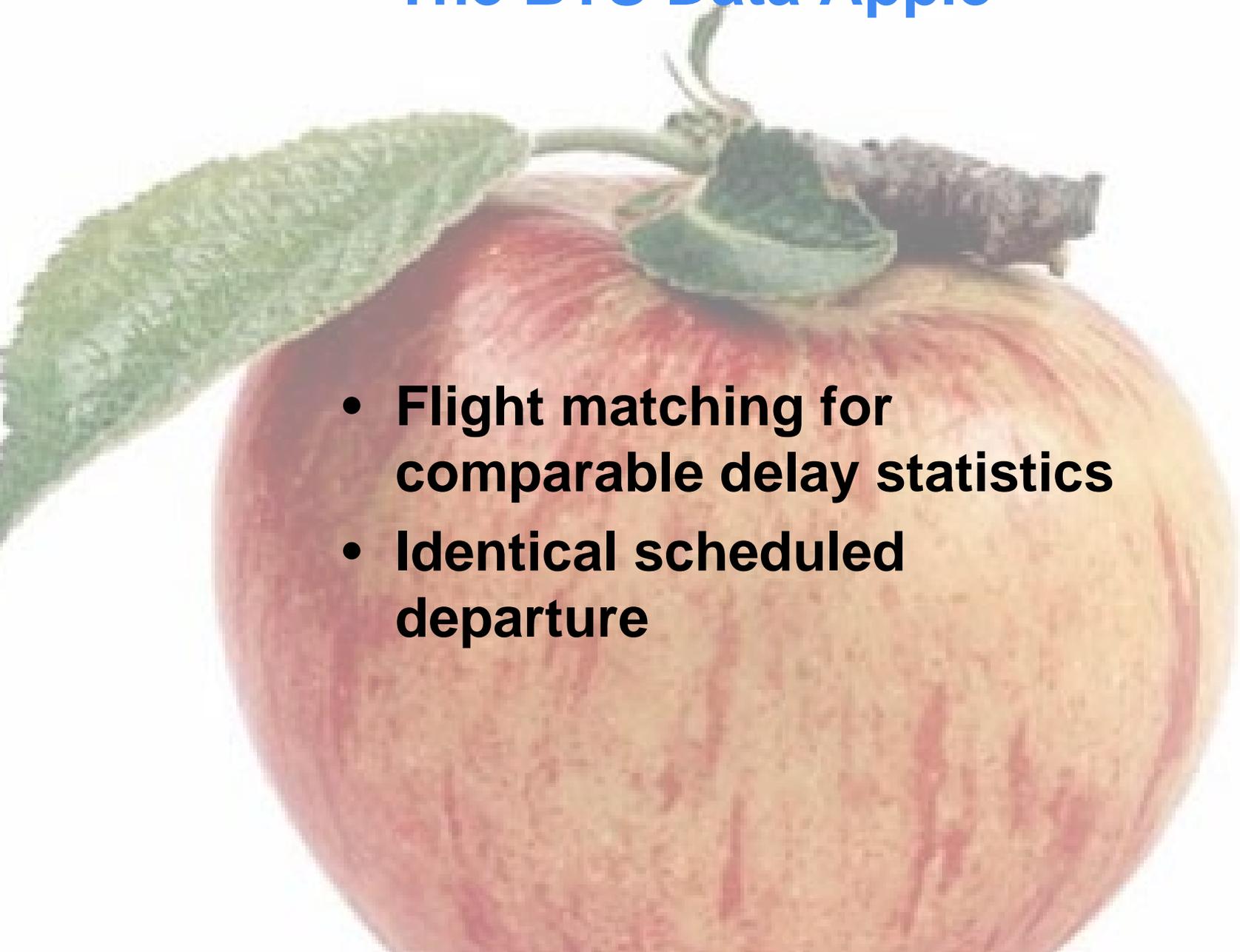
KLGA Departure Comparison



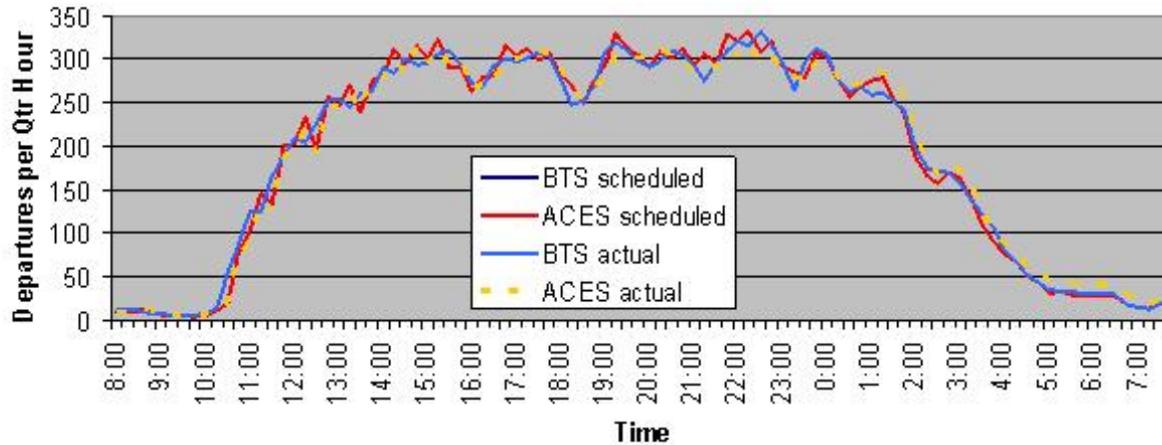
KLGA Arrival Comparison



# The BTS Data Apple

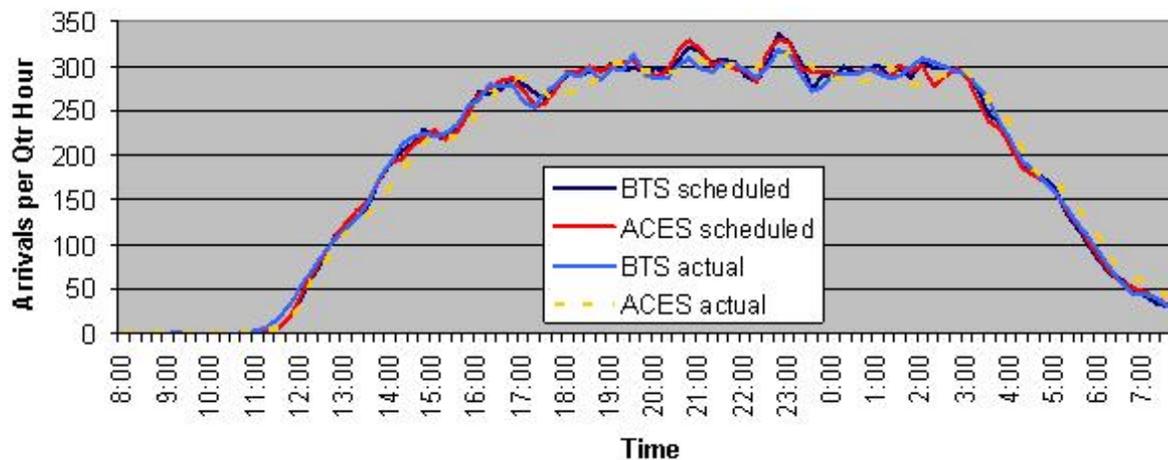
- 
- A large, detailed image of a red and yellow apple with a green leaf and stem, positioned in the background of the slide.
- **Flight matching for comparable delay statistics**
  - **Identical scheduled departure**

## Gate Departures (Smoothed by 3 Qtr Hours)



Departures	Sched	Actual
Correlation	100%	96.2%
Smoothed Correlation	100%	99.9%
Average Difference (BTS-ACES) per qtr	0.0	-0.01
Percent BTS Traffic	100%	100%

## Gate Arrivals (Smoothed over 3 Qtr Hours)

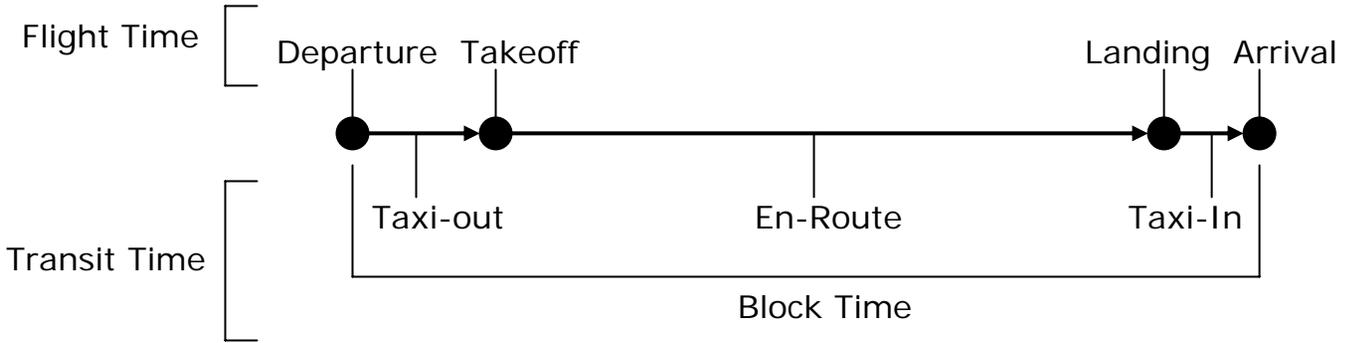


Arrivals	Sched	Actual
Correlation	99.2%	98.4%
Smoothed Correlation	99.3%	99.4%
Average Difference (BTS-ACES) per qtr	0.05	1.36
Percent BTS Traffic	100%	99.3%

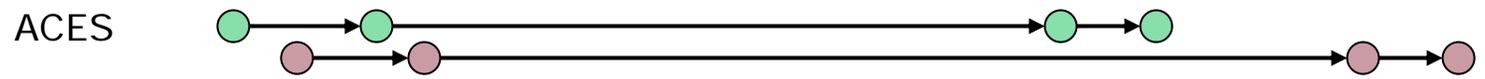
# Delay and Time Metric Definitions

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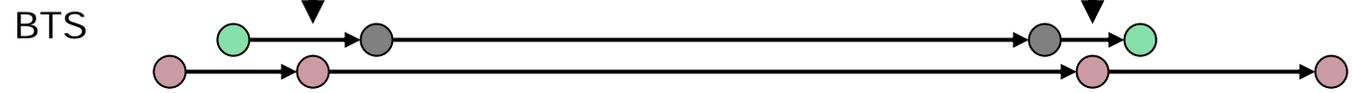
- Scheduled ● (green)
- Actual ● (red)
- Unknown ● (grey)



$$\text{Delay} = \text{Actual} - \text{Scheduled}$$

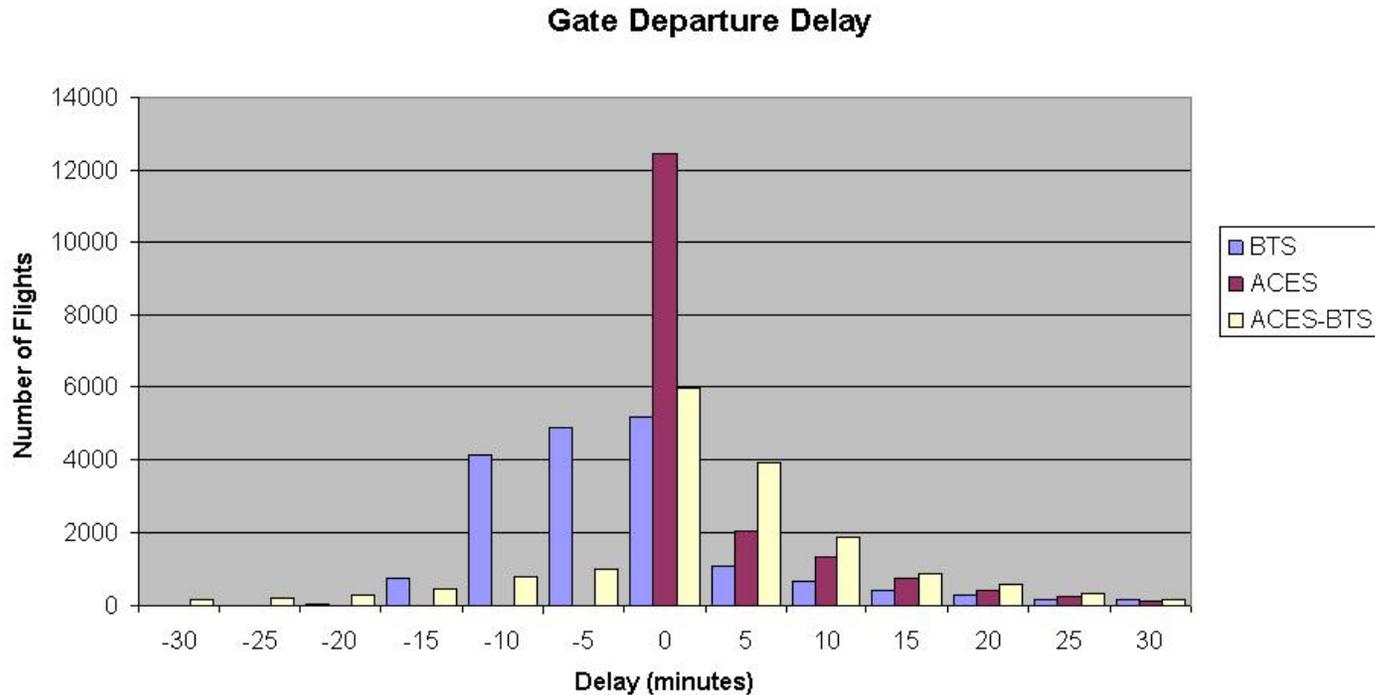


Use ACES unimpeded taxi time



# Results: Gate Departure Delay

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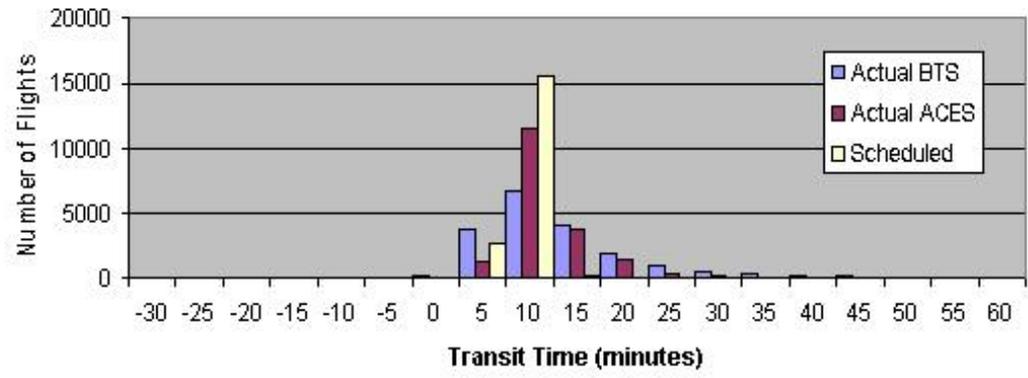


Gate Departure Delay	ACES	BTS	diff
Mean	12.51	2.23	10.28
Standard Deviation	46.46	16.90	49.17
Median	0.97	-1.00	4.20
5% Trimmed Mean	4.85	-0.22	5.44
Min	0.00	-109.00	-315.00
Max	996.50	315.00	970.50

# Results: Taxi Out

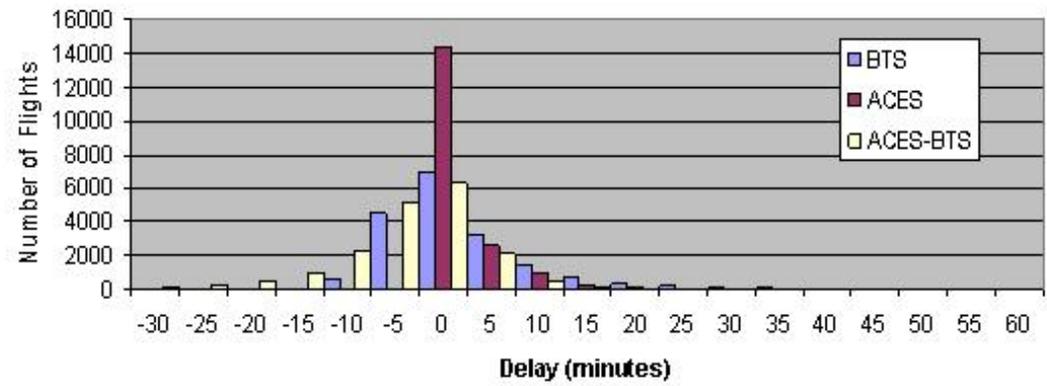
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Taxi Out Transit Time



Scheduled Time	ACES	BTS	diff
Mean	10.90	10.90	0.00
Standard Deviation	1.44	1.44	0.00
Median	11.00	11.00	0.00
5% Trimmed Mean	10.89	10.89	0.00
Min	6.70	6.70	0.00
Max	15.40	15.40	0.00

Taxi Out Delay



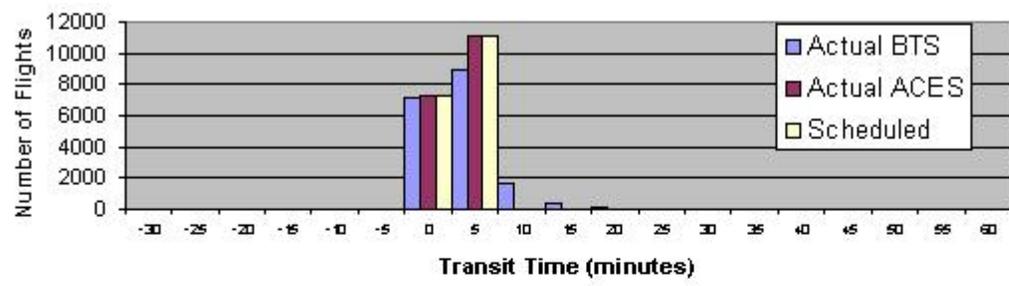
Actual Time	ACES	BTS	diff
Mean	13.82	15.39	-1.57
Standard Deviation	4.58	8.34	8.05
Median	12.45	13.00	-0.28
5% Trimmed Mean	13.41	14.59	-1.03
Min	6.70	0.00	-82.60
Max	53.30	93.00	38.30

Delay	ACES	BTS	diff
Mean	2.93	4.50	-1.57
Standard Deviation	4.06	7.90	8.05
Median	1.23	2.50	-0.28
5% Trimmed Mean	2.42	3.71	-1.03
Min	0.00	-11.50	-82.60
Max	42.40	82.60	38.30

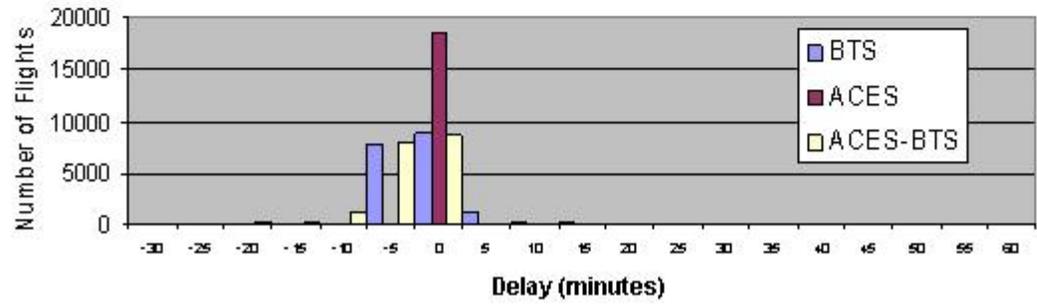
# Results: Taxi In

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Taxi In Transit Time



Taxi In Delay



Scheduled Time	ACES	BTS	diff
Mean	4.96	4.96	0.00
Standard Deviation	0.94	0.94	0.00
Median	5.00	5.00	0.00
5% Trimmed Mean	4.98	4.98	0.00
Min	2.20	2.20	0.00
Max	6.78	6.78	0.00

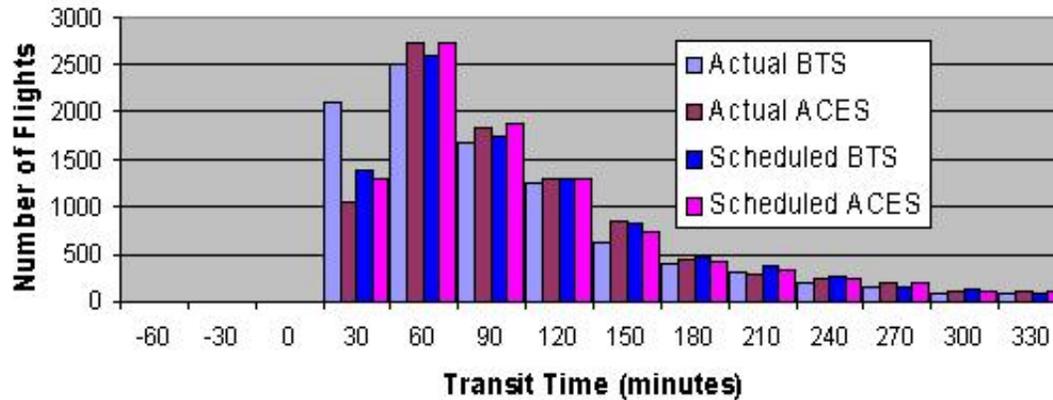
Actual Time	ACES	BTS	diff
Mean	4.96	6.04	-1.08
Standard Deviation	0.94	4.11	3.87
Median	5.00	5.00	-0.42
5% Trimmed Mean	4.98	5.60	-0.69
Min	2.20	-131.00	-69.72
Max	6.78	75.00	136.00

Delay	ACES	BTS	diff
Mean	0.00	1.08	-1.08
Standard Deviation	0.00	3.87	3.87
Median	0.00	0.42	-0.42
5% Trimmed Mean	0.00	0.69	-0.69
Min	0.00	-136.00	-69.72
Max	0.00	69.72	136.00

# Results: Enroute

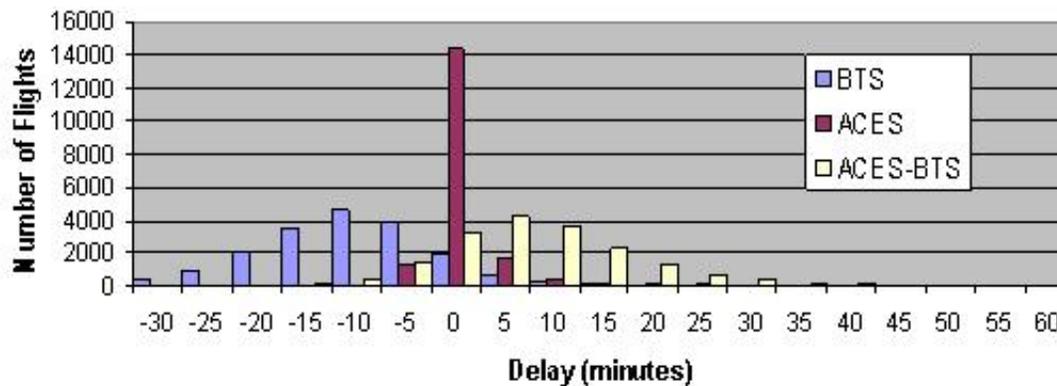
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### Enroute Transit Time



Scheduled Time	ACES	BTS	diff
Mean	112.62	112.45	0.16
Standard Deviation	67.86	68.73	9.35
Median	93.82	93.60	0.22
5% Trimmed Mean	105.81	105.77	0.08
Min	26.75	22.70	-44.12
Max	641.38	641.50	66.95

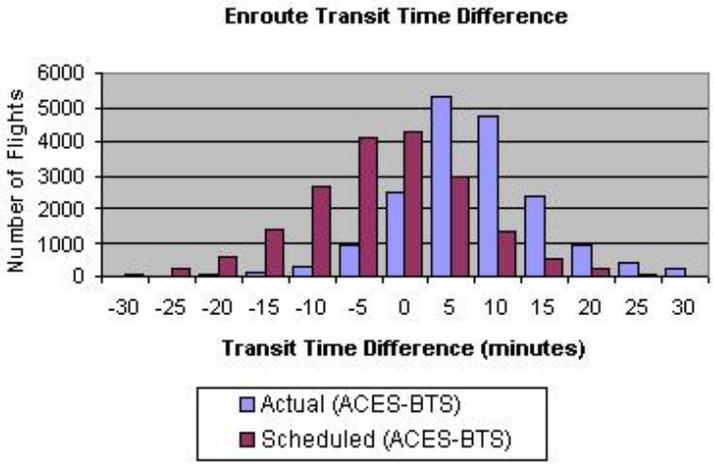
### Enroute Delay



Actual Time	ACES	BTS	diff
Mean	115.75	104.55	11.20
Standard Deviation	69.62	67.10	12.45
Median	96.33	85.00	9.97
5% Trimmed Mean	108.81	97.84	10.41
Min	-28.08	0.00	-668.1
Max	590.75	640.00	203.67

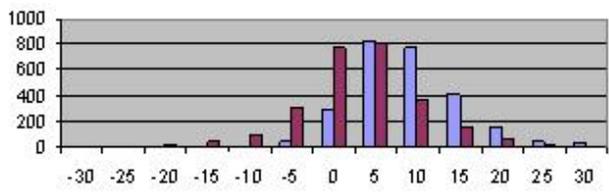
Delay	ACES	BTS	diff
Mean	3.13	-7.90	11.03
Standard Deviation	9.22	8.86	13.28
Median	1.27	-7.52	9.58
5% Trimmed Mean	2.00	-7.84	10.32
Min	-669.47	-99.50	-667.9
Max	172.92	144.28	184.5344

# Enroute Time Difference by Airline

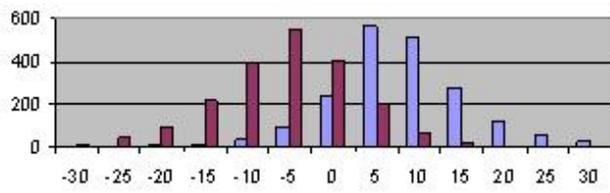


MEAN	Scheduled	Actual
SWA	5.64	12.18
AAL	-2.97	11.83
DAL	-1.17	13.05
UAL	-0.26	13.85
NWA	2.70	9.81
EGF	-0.58	9.72
Stdev All Airlines	3.48	1.72

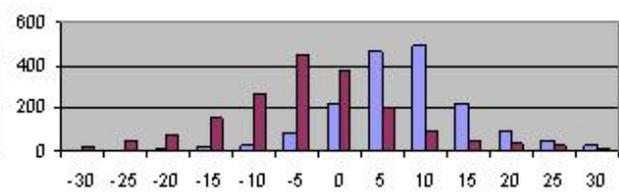
**Southwest (SWA)**



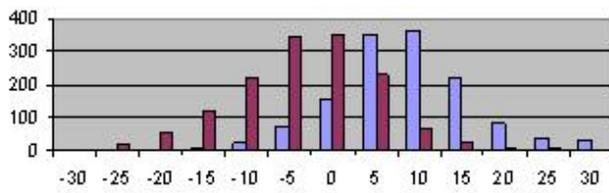
**American (AAL)**



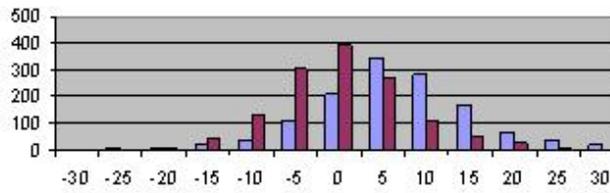
**Delta (DAL)**



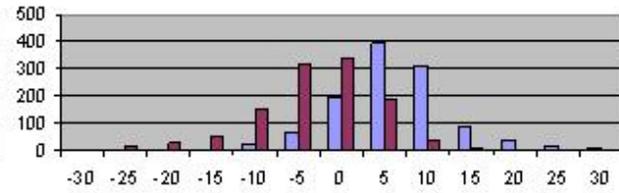
**United (UAL)**



**Northwest (NWA)**



**American Eagle (EGF)**



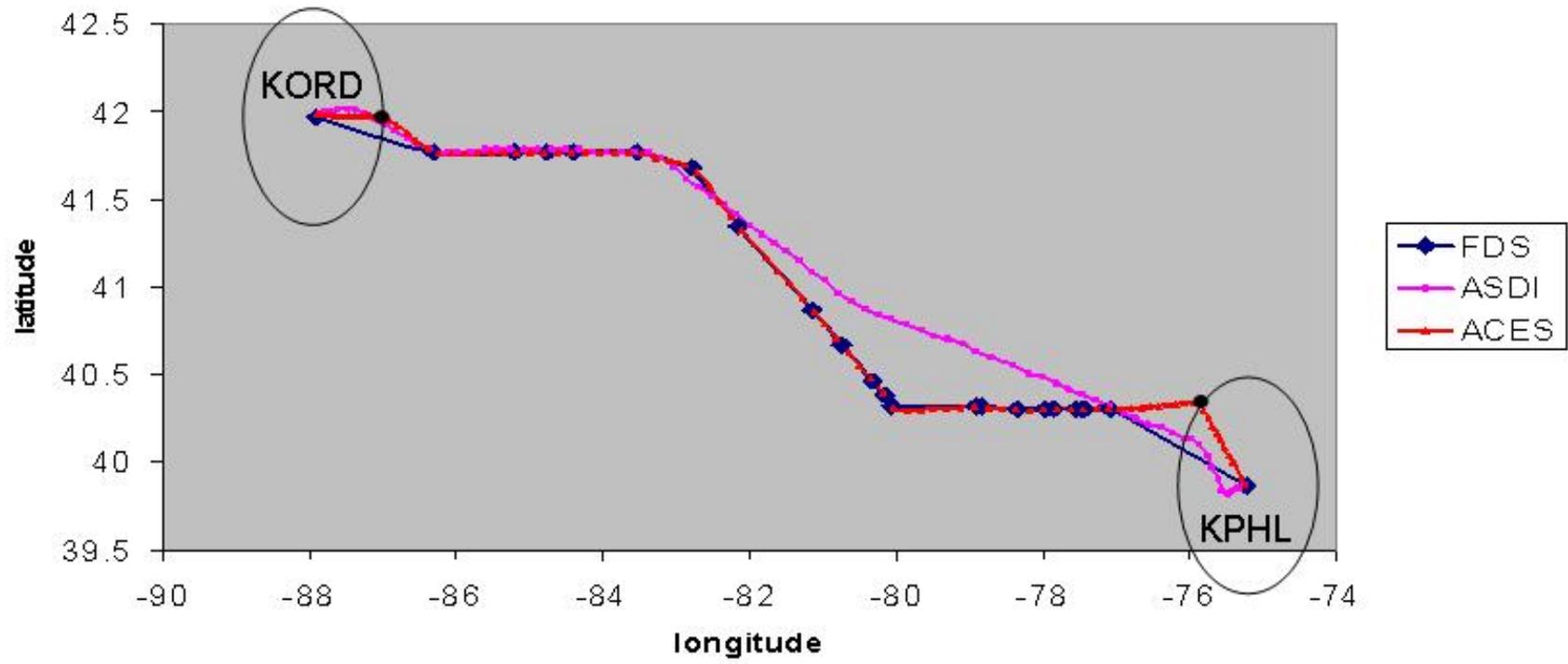
# Flight Tracking Position

## Sample Flight AAL1372 from KORD to KPHL

ACES	Taxi Out	Enroute	Taxi In	Gate Dep
Scheduled	11.0	92.9	4.6	
Actual	11.0	133.9	4.6	
Delay	0.0	41.0	0.0	0.0

BTS	Taxi Out	Enroute	Taxi In	Gate Dep
Scheduled	11.0	96.3	4.6	
Actual	12.0	80.0	6.0	
Delay	1.0	-16.3	1.4	-10.0

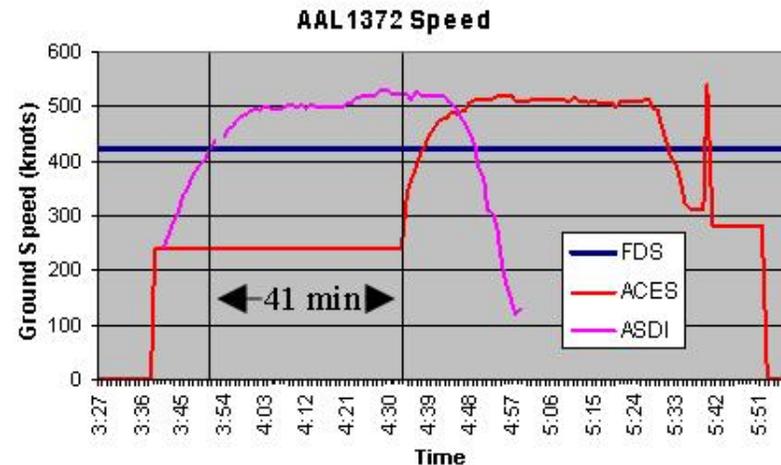
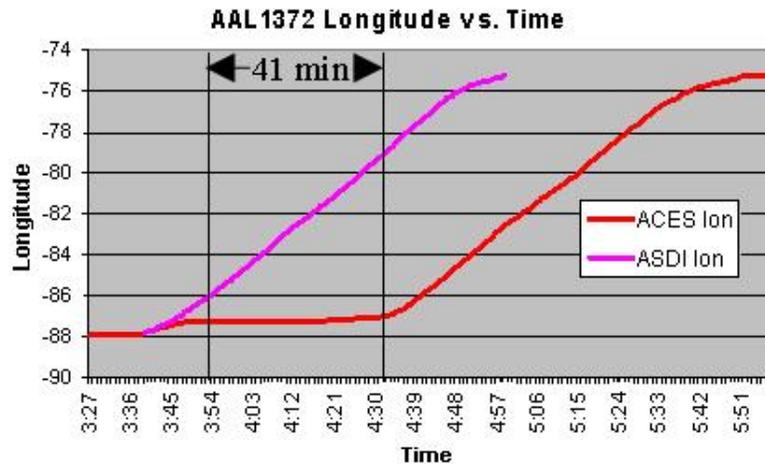
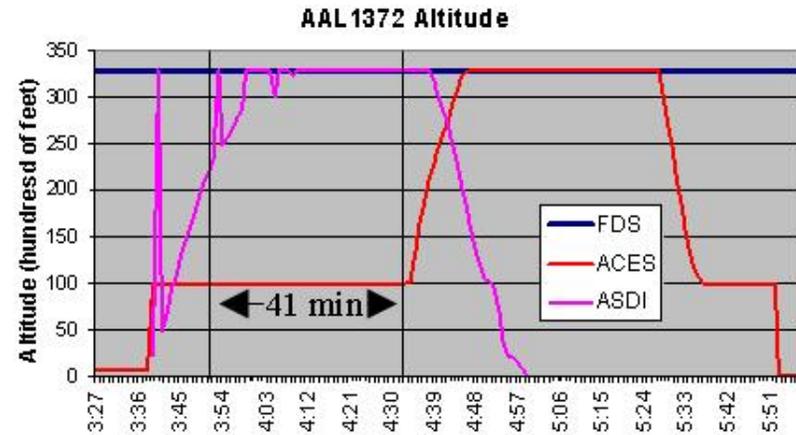
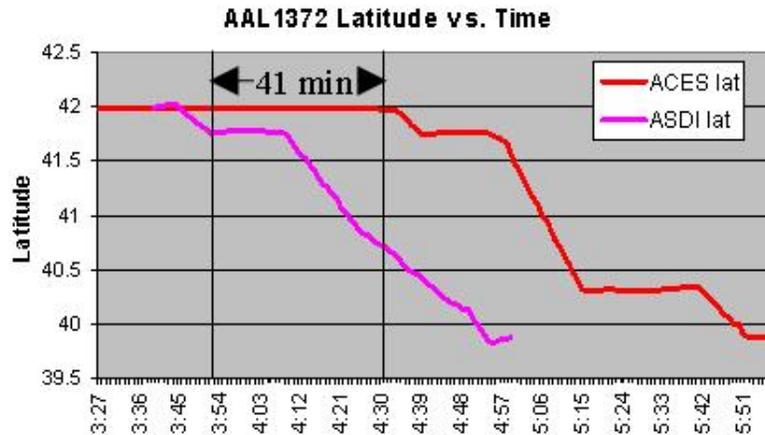
AAL1372 - KORD to KPHL



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# Flight Tracking by Time

- Departure meter fix separation: 25 flights in the TRACON exit queue adds 41 minutes of delay.

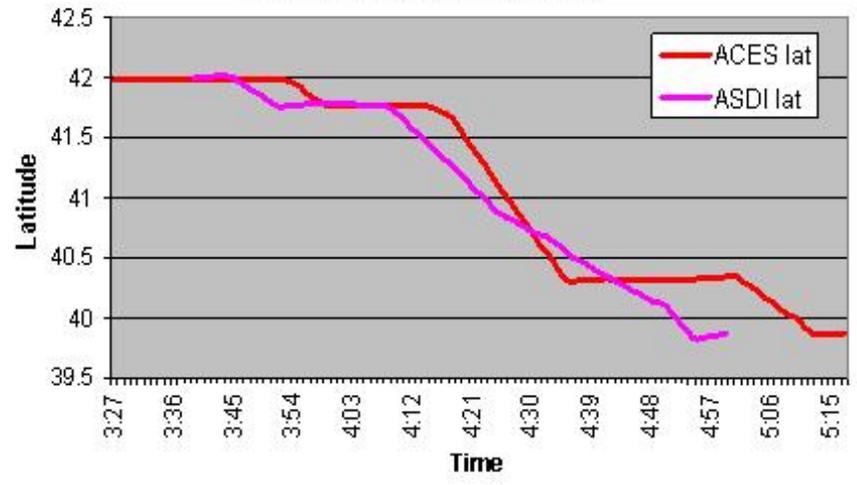


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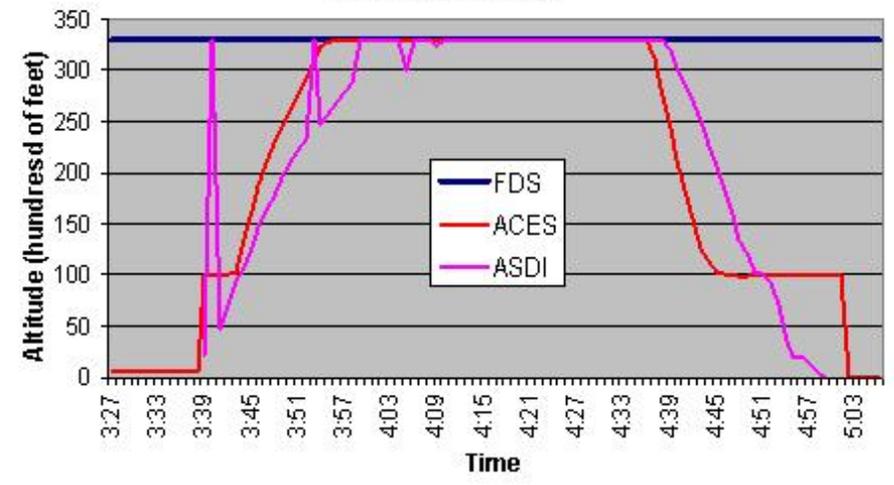
# Tracking Without TRACON Delay

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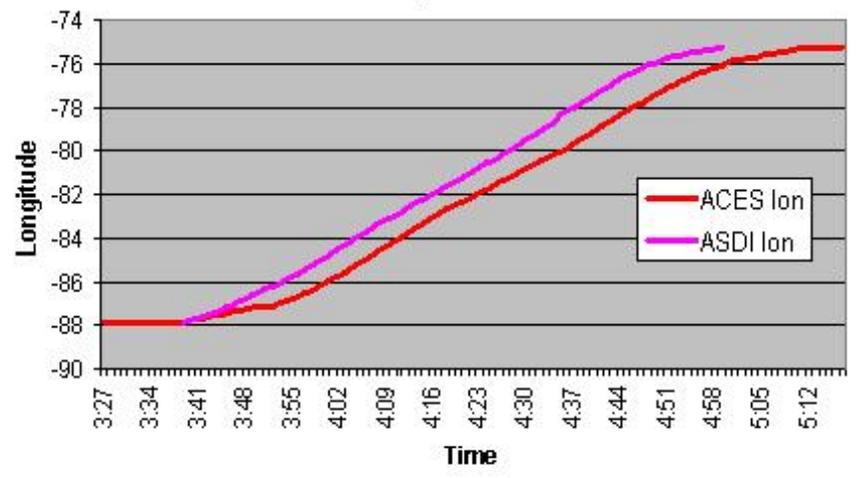
AAL1372 Latitude vs. Time



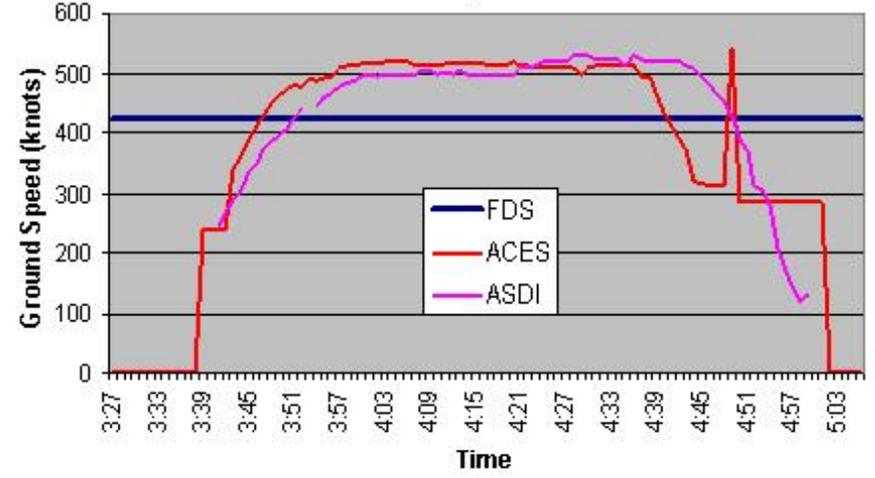
AAL1372 Altitude



AAL1372 Longitude vs. Time



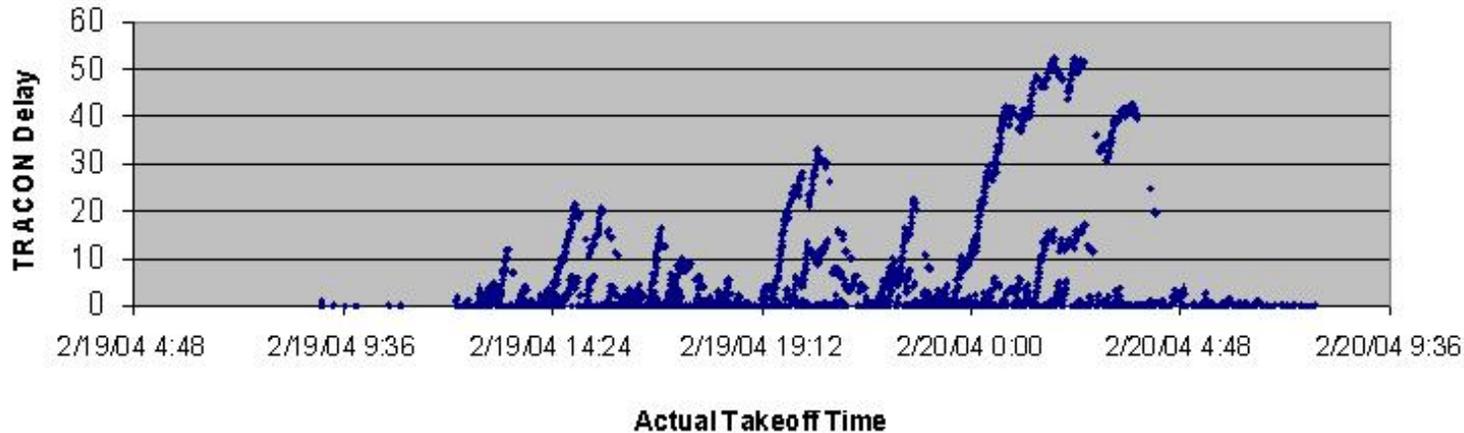
AAL1372 Speed



# TRACON Delay Analysis

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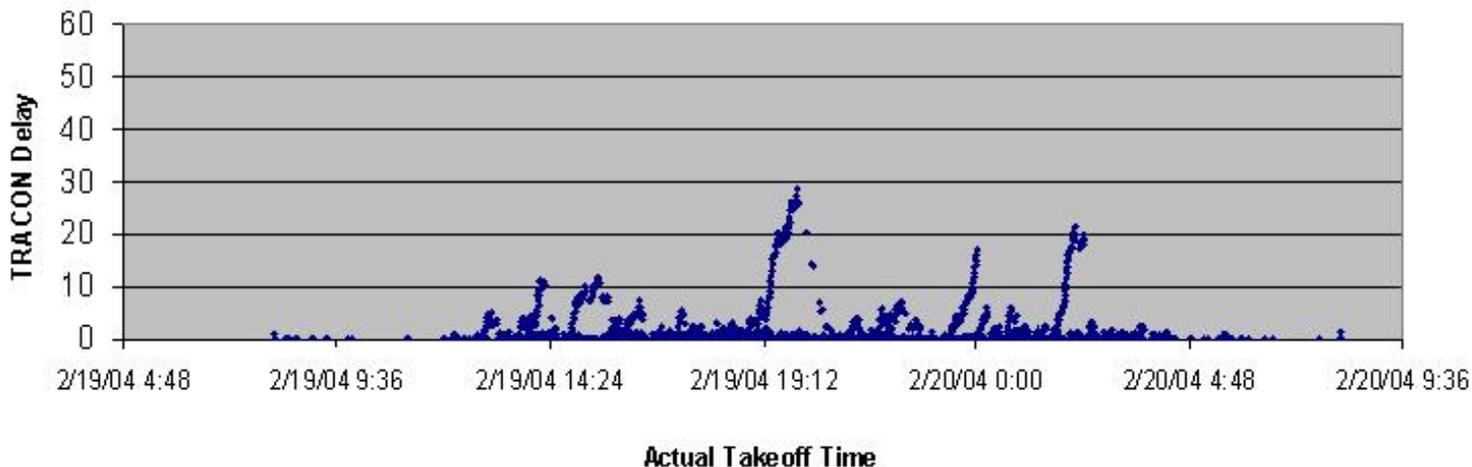
**KORD TRACON Delay by Actual Takeoff Time**



Number of flights with more than 10 min of TRACON delay

KORD	369
KDFW	78
KMEM	9
KMIA	6
KATL	3
KILN	2
KDEN	1
KDTW	1

**KDFW TRACON Delay by Actual Takeoff Time**



# Validation Conclusions

- **Given appropriately designed inputs for 2/19/2004, ACES compares very well to real world data.**
- **Both departure and arrival counts compare well to ASPM. FDS is likely higher than 91% of ASPM.**
- **Negative Delay in the real world**
- **Airline specific flight time padding is evident.**
- **Departure meter fix separation for the nodal model places higher than normal constraints within the terminal area for high throughput airports.**

# Future Work

- **Analysis**
  - East bound vs. Westbound flights
  - Sector loading comparisons
  - City Pair and Regional delay comparisons
  - How do stats change with time of day?
- **Simulation Runs**
  - Turn Departure Meter Fix Separation off or introduce generic enhanced terminal area models with more meter fixes.
  - Use maximum throughput as capacity if higher than original ACES sample.
  - Turn other models on in turn.
  - Extend to other weather days.